

SMITHSONIAN

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VOL. 111



"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES,
AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

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A. WETMORE,

Secretary of the Smithsonian Institution.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 1

MIRANDOLLE'S FOREST FALCON

(WITH TWO PLATES)

BY

HERBERT FRIEDMANN

Curator, Division of Birds, U. S. National Museum



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(WITH TWO PLATES)

Mirandolle's forest falcon, *Micrastur mirandollei* (Schlegel), is one of the least known of American hawks in spite of a very extensive range, extending from Costa Rica to Bolivia, and it has long been a rare bird in museum collections. So little material was available for study that in 1932 Griscom (Bull. Mus. Comp. Zool., vol. 72, p. 317) was moved to write of Wedel's eastern Panamanian collection that "a series of five specimens of this very rare Hawk from one locality is unprecedented. . . ." Since that time additional examples have been taken, and in 1941 Griscom and Greenway (Bull. Mus. Comp. Zool., vol. 81, p. 418) separated the birds of the Caribbean coast of extreme eastern Panamá under the name *M. m. extimus*, as they observed that two adults from there differed from a single Brazilian adult and from the description of the type from Surinam in having "much narrower and paler tailbands and in having the white underparts washed with richer buff. Judging by an immature bird and an intermediate specimen also from eastern Panamá, the differences described above have nothing to do with immaturity. . . ." Their comparative material was admittedly inadequate, but, fortunately, their action proves to be correct.

Through the courtesy of the officials of the American Museum of Natural History, Carnegie Museum, Chicago Natural History Museum, Museum of Comparative Zoology, and the Academy of Natural Sciences of Philadelphia, I have been able to add to the limited material stored in Washington, and have brought together by far the largest and most representative series of this species ever assembled, 26 specimens in all. These birds, young and adult of both sexes, clearly substantiate the validity of *extimus*, as the accompanying figures (pls. 1, 2) show, but also indicate that its range is much more extensive than hitherto thought. It is because of the rarity of this hawk that I have felt it worth while to illustrate the races in this paper, as otherwise it would take an equal amount of borrowing for anyone

else to assemble an adequate corpus of data to elucidate them. The illustrations show representative samples of both races, including in each case immature as well as adult birds, and males as well as females. To show more examples in each picture would have reduced their scale too much without in any way adding to the demonstration of the distinctness of their racial characters.

The races and their ranges are as follows:

Micrastur mirandollei extimus is characterized by having the pale bands on the dorsal surface of the rectrices narrow, white or almost white with a medial dusky band. This is true of young and old birds alike. The series studied does not uphold the supposed character of a richer buffy wash on the white underparts. This race ranges from Costa Rica (Talamanca) and Panamá (scattered records from the Caribbean slope, one from the Pacific slope, Permé, Obaldía, Panama Railway Line), south to the Chocó area of western Colombia (Río Juradó, Río Baudó, Río Yarubida, where a series of 10 specimens was collected by von Sneider).

Micrastur mirandollei mirandollei has the pale bands on the dorsal surface of the rectrices somewhat broader and much duskier—grayish brown, becoming whitish on the inner webs of the lateral tail feathers, and, in young birds, the dusky margins of the feathers of the throat and breast paler, more washed out than in corresponding examples of *extimus*. This form ranges from Colombia east of the eastern Andes (Meta (Quenane) and Caquetá)¹ to Venezuela (Cerro Yapacana, Upper Orinoco; Cerro Duida), and the Amazonian basin of

¹ Unfortunately, I have not seen either of these eastern Colombian specimens, and Nicéforo María's example from Meta is figured (*Caldasia*, vol. 4, No. 19, p. 321, May 30, 1947) from the underside and consequently does not show the dorsal appearance of the tail bands. It is, however, a young bird, and, as far as may be judged from the photograph, has fairly pale edges to the pectoral and upper abdominal feathers, which would suggest its being of the nominate race. This is not clarified or too well borne out by the accompanying description, wherein it is said that the tail feathers are tipped with white, but have the other bars grayish brown, with white edges, which might even seem to suggest *extimus*! I understand that during the recent uprising in Bogotá, Brother Nicéforo's collections were lost in the destruction of the building that housed them. No eastern Colombian examples are known in any collection outside of Colombia. Fortunately, in response to my inquiry, Dr. Armando Dugand has supplied the necessary information to enable me to place the Caquetá bird (and hence, by inference, the Meta example) as typical *mirandollei*. He writes me that the specimen from Morelia, Caquetá, has the two central rectrices with "three bars plus one terminal; the bars are grayish brown, only very slightly paler than the dark brown of the feathers . . . the other rectrices show white bars only on the inner webs. . . ."

Brazil (Rio Juruá, Villa Braga, Santarém, Tapajóz River, Beireio, Rio Majary, Rio Acorá, Rio Jamundá, São Gabriel, Igarapa Aniba, Piquiatuba, Manacapuru, and Allianca, Pará), southeast to Espirito Santo (Rio Doce), and northeast to British Guiana (Carimang River, Ituribisi River, Courantyne, Bartica, Arawai River), Dutch Guiana, and French Guiana (Cayenne), and south to eastern Perú (Chyvetas, Yurimaguas) and to Bolivia (Santa Ana, near La Paz, on the Río Corioco).

The nominate race averages larger than the northern form as the following measurements show, but the overlap is too great for size to be used as a diagnostic character.

Micrastur mirandollei mirandollei: 11 males (including 5 from the literature), wing 220-241 (230.5); tail 179-202 (189.1); culmen from cere 20-23 (20.8); tarsus 70-76.2 (75.5); middle toe without claw 35.7-37.2 (36.7 mm.); 7 females, wing 221-248 (233.0); tail 180-208 (190.7); culmen from cere 19.9-22.4 (20.9); tarsus 73-86 (77.9); middle toe without claw 34.2-38.8 (36.2 mm.). In this connection it may be mentioned that Hellmayr (Nov. Zool., vol. 17, p. 409, 1910) gives the measurements of an old adult female from Allianca, Brazil, as wing 265, tail 200, culmen 24, and tarsus 55 mm. The wing is much longer and the tarsus much shorter than in any birds I have examined.

Micrastur mirandollei extimus: 7 males, wing 215-237 (221.3); tail 182-200 (191.5); culmen from cere 20-23.3 (21); tarsus 74.1-81 (77.6); middle toe without claw 32.5-38 (35.1 mm.); 7 females, wing 220-228 (224.3); tail 187-195 (191); culmen from cere 20.2-22.4 (21.4); tarsus 78-84 (80.1); middle toe without claw 35.1-38 (36.1 mm.).

It appears from these figures that this is one of the relatively few hawks in which there is little or no difference in size between the sexes. A detailed description of its plumages, given below, completes our present knowledge of this rare forest falcon.

Micrastur mirandollei mirandollei: ADULT (sexes alike in coloration): Forehead, crown, occiput, nape, scapulars, interscapulars, back, rump, upper tail coverts, upper wing coverts, and remiges deep neutral gray with a slate tinge, the top of head somewhat darker; the inner webs of the remiges white for their basal two-thirds or more, and crossed by four fairly broad dark mouse-gray bands and somewhat mottled with deep mouse gray on the more distal portion of the whitish area; the fifth (from the outside) primary the longest, the first (outermost) the shortest; tail chaetura black tipped with white or buffy white and crossed by three fairly broad grayish-brown bands, these bands becoming whitish on the inner webs of the lateral

feathers; lores and orbital area bare, a slight line below the eye, the cheeks, and the auriculars like the crown; the posterior auriculars shading to buffy white; chin, throat, breast, abdomen, sides, flanks, thighs, and under tail coverts whitish to pale light pinkish buff, the feathers, especially of the breast and sides, often, but not always, with very fine dusky shaft lines; under wing coverts whitish to pinkish buff, the lower ones mixed or banded with deep neutral gray; iris yellowish brown; cere and base of both mandibles yellowish, the bill otherwise horn black; tarsi and toes bright yellow; claws black.

IMMATURE: Similar to the adult, but with a brownish slate tinge on the upperparts; the pale tail bands washed with pale fulvous; the entire underparts with a buffy wash; the feathers of the breast and sides with prominent dusky shaft streaks; bill blackish except basally where it is yellow.

JUVENAL: Similar to adult, but upperparts dull fuscous with a faint slate wash; underparts whitish with a buffy wash on the throat, breast, sides, flanks, and upper abdomen, but not on chin or vent; each feather of the throat, breast, sides, flanks, and upper abdomen with a broad border of fulvous drab to hair brown, producing a conspicuously scalloped appearance; bill yellow, slightly dusky along the proximal portion of the culmen.

NATAL DOWN: Unknown.

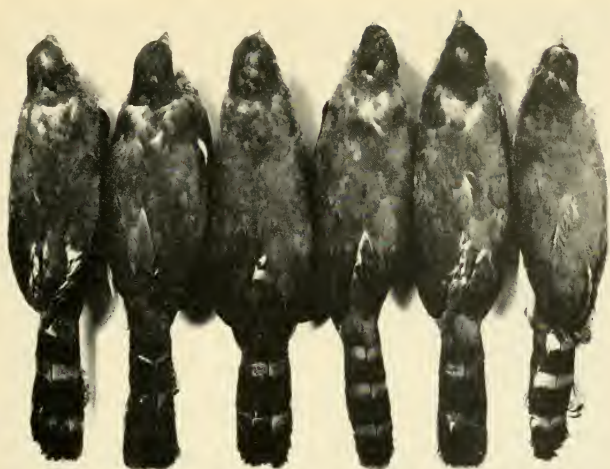
Micrastur mirandollei extimus: ADULT: Like that of the nominate race except for the color of the tail bands, as shown in the illustrations and mentioned above. (No specimen from the range of *extimus* shows any approach to *mirandollei*, but one adult female of the latter form, from Rio Jamundá, Brazil (Amer. Mus. Nat. Hist. 283244), and one from Cerro Duida, Venezuela (Amer. Mus. Nat. Hist. 272322), show some resemblance to *extimus* in this respect. However, 2 specimens out of 11 is not a serious exception to the general picture, and of these 2, the Cerro Duida bird is less aberrant than the one from Rio Jamundá.)

IMMATURE: Similar to that of typical *mirandollei*.

JUVENAL: Similar to that of the nominate race but with the broad edges of the feathers of the throat, breast, sides, flanks, and upper abdomen averaging darker—dark hair brown.

NATAL DOWN: Unknown.

Specimens examined.—*M. m. mirandollei*, 11: Venezuela 2, Brazil 6, British Guiana 1, French Guiana 1, Bolivia 1. *M. m. extimus*, 15: Costa Rica 1, Panamá 4, western Colombia 9, without locality 1.



MICRASTUR MIRANDOLLEI MIRANDOLLEI (SCHLEGEL)

Upper, dorsal view; lower, ventral view of same individuals (1 immature, 5 adult) showing lack of correlation between age and the character of the dorsal tail band. The specimens figured are from Venezuela, Brazil, British Guiana, French Guiana, and Bolivia.



MICRASTUR MIRANDOLLEI EXTIMUS GRISCOM AND GREENWAY

Upper, dorsal view; lower, ventral view of same individuals (4 juvenal, 2 adult) showing that age is not a factor in the character of the dorsal tail bands. The specimens figured are from Costa Rica, Panamá, and western Colombia.



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PREHISTORY AND THE MISSOURI
VALLEY DEVELOPMENT
PROGRAM

SUMMARY REPORT ON THE MISSOURI RIVER
BASIN ARCHEOLOGICAL SURVEY IN 1947

(WITH EIGHT PLATES)

BY

WALDO R. WEDEL

*Associate Curator, Division of Archeology,
U. S. National Museum*



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INTRODUCTION

This report summarizes the field and laboratory activities in archeology and paleontology by the Missouri River Basin Survey during the calendar year 1947. It is not a complete or final statement of accomplishments during the year, nor does it undertake to set forth the opinions of the various staff members who have been directly responsible for the field and laboratory researches, and whose findings constitute much of the basic information on which this summary is based. Essentially, it is a report of progress as of December 31, 1947, at the end of the first 18 months in a scientific salvage program linked to "the most comprehensive and far-reaching river basin development plan ever undertaken in America"—the harnessing of the Missouri River and its tributaries.

The general background, organization, and basic objectives of the Missouri River Basin Survey have been adequately set forth elsewhere and need not be detailed again here.¹ The project represents but one regional phase of the River Basin Surveys, a nation-wide archeological and paleontological scientific salvage program under the direction of Dr. F. H. H. Roberts, Jr., for the Smithsonian Institution. This program is based directly on a memorandum of understanding formulated in 1945 between the Institution and the National Park Service, and indirectly on a series of interbureau agreements between the Park Service, the Bureau of Reclamation, and the Corps of Engineers. Its purpose, briefly, is to locate, record,

¹ See Smithsonian Misc. Coll., vol. 107, No. 6, Apr. 23, 1947; and Amer. Antiq., vol. 12, No. 4, pp. 209-225, April 1947.

and evaluate the archeological and paleontological resources that will be affected by the many Federal water-control projects planned or under construction by the Bureau of Reclamation, Department of the Interior, and the Corps of Engineers, Department of the Army; to transmit this information to the National Park Service; and to recommend, where necessary, the procedures needed for recovery of as much as possible of the scientific information which would otherwise be lost. As excavation at key sites supersedes the survey and test digging which alone have so far been possible, it will be the Smithsonian's responsibility to direct the Federal phases of this work as well.

Funds to support the operations thus far have come from the Bureau of Reclamation through the National Park Service to the Smithsonian. For the most part, they have been for survey only. During fiscal year 1948, limited excavation funds were made available for work at Angostura, S. Dak., Boysen, Wyo., and Heart Butte, N. Dak.; of these units, only Boysen was visited for limited excavations during the calendar year 1947.

In the Missouri Basin, as elsewhere, American archeology will long be indebted to the governmental agencies whose efforts and financial support are making possible the salvage operations. Through the enlightened conservation policy and excellent cooperation of the National Park Service and the Bureau of Reclamation, what threatened to be a program of wholesale destruction of scientific resources in the Basin promises, if properly carried through, to become one of the most comprehensive archeological and paleontological research projects ever undertaken in this region.

It is a pleasure to note here that throughout 1947 the relationships of the Missouri River Basin Survey with other agencies have remained, on the whole, cordial and pleasant. Close contact has been maintained at all times with the Missouri River Basin Recreation Survey, Region 2, National Park Service, in which office Chief Recreation Planner Guy D. Edwards and Archeologist J. D. Jennings have been particularly helpful. The Bureau of Reclamation, besides financing the work, has freely furnished maps, construction schedules, and other materials and information, as requested. The Corps of Engineers has likewise been generous in providing topographic maps and other information; in the Omaha District office T. E. Huddleston has been very helpful in the archeological interpretation of aerial photographs of the upper Missouri Valley. Local and regional representatives of all these agencies, project engineers, and others have been uniformly cooperative. The same may be said in regard to State and other non-Federal agencies, as well as of numerous private indi-

viduals. The active interest of the archeological profession and of learned societies, as expressed through the Committee for the Recovery of Archeological Remains, has also been of very real assistance.

The Missouri River Basin Survey was established in July 1946, with headquarters at Lincoln, Nebr. In 1946, and throughout most of 1947, field activities were in the main restricted to preliminary reconnaissance and survey at the most urgent projects, that is, where actual dam construction had been initiated or where preconstruction activities were nearing completion and construction was expected to start in the near future. Some test-pitting and small-scale excavation was undertaken near the close of the 1947 field season, but in general it can be said that the work during the first 18 months constituted the initial phase of the program.

By the end of 1947, reconnaissance parties of the River Basin Surveys had visited and partially or completely surveyed 44 Bureau of Reclamation and 6 Corps of Engineers projects in the Missouri River watershed. These were distributed throughout seven States, as follows: Colorado, 3; Kansas, 6; Montana, 4; Nebraska, 16; North Dakota, 10; South Dakota, 5; Wyoming, 6. A total of 598 sites of archeological interest were located and recorded, many of them previously unreported. That this number probably represents only a fraction of those which actually await discovery and recording is indicated by the many new sites found in intensive survey at certain proposed units which had previously been examined only in preliminary fashion. Thus, for example, at Glendo in Wyoming 8 sites were recorded during a 4-day reconnaissance in 1946, but 35 additional locations were hunted out during a 3-week visit in 1947. Other units gave comparable results, thus demonstrating the need for thorough search at any proposed reservoir site before water is impounded.

A list of reservoir projects visited from July 1946 to December 1947, with the number of archeological sites so far recorded for each, follows:

Bureau of Reclamation:

RESERVOIRS	SITES	RESERVOIRS	SITES
1. Amherst, Nebr.	5	9. Brewster, Nebr.	1
2. Anchor, Wyo.	3	10. Broncho, N. Dak.	9
3. Angostura, S. Dak.	5	11. Buffalo Creek, Dawson County, Nebr.	1
4. Beaver City, Nebr.	4	12. Buffalo Creek, Dundy County, Nebr.	1
5. Blue Horse, S. Dak.	0	13. Cairo, Nebr.	0
6. Bonny, Colo.	3	14. Canyon Ferry, Mont.	33
7. Box Butte, Nebr.	1		
8. Boysen, Wyo.	75		

Bureau of Reclamation (Cont'd):

RESERVOIRS	SITES	RESERVOIRS	SITES
15. Cedar Bluff, Kans.....	4	30. Medicine Creek, Nebr....	20
16. Crosby, N. Dak.....	1	31. Medicine Lake, Mont....	8
17. Culbertson, Nebr.	1	32. Mullen, Nebr.	8
18. Deerfield, S. Dak.....	0	33. Norton, Kans.	3
19. Des Lacs, N. Dak.....	0	34. Oregon Basin, Wyo....	28
20. Devils Lake, N. Dak....	5	35. Pioneer, Kans.	1
21. Dickinson, N. Dak.....	3	36. Red Willow, Nebr.....	5
22. Enders, Nebr.	4	37. Rock Creek, Nebr.....	1
23. Ericson, Nebr.	5	38. Rockville, Nebr.	0
24. Glendo, Wyo.	43	39. Shadehill, S. Dak.....	6
25. Heart Butte, N. Dak....	4	40. Sheyenne, N. Dak.....	11
26. Jamestown, N. Dak....	7	41. Tiber, Mont.	53
27. Kirwin, Kans.	1	42. Wilson, Kans.	6
28. Kortess, Wyo.	1	43. Wray, Colo.	5
29. Lake Solitude, Wyo....	0	44. Yellowtail, Mont.	3

Corps of Engineers:

45. Baldhill, N. Dak.....	10	49. Harlan County, Nebr....	23
46. Cherry Creek, Colo....	6	50. Kanopolis, Kans.	18
47. Fort Randall, S. Dak....	93		
48. Garrison, N. Dak.....	70		598

The results of paleontological work by the Missouri River Basin Survey during 1947 are summarized elsewhere in this report.

PERSONNEL

The professional staff throughout the year included six archeologists: Paul L. Cooper, in charge of the field office during the writer's absences in Washington; Robert B. Cumming, Jr., laboratory supervisor; Wesley L. Bliss, Marvin F. Kivett, J. J. Bauxar, and Jack T. Hughes. Dr. T. E. White, on leave of absence from the Museum of Comparative Zoology, Harvard University, joined the River Basin Surveys in April, and throughout most of the year he was engaged in paleontological field work in the Missouri River Basin.

Full-time laboratory and office personnel included Mrs. Ina May Reagan, advanced from temporary office assistant to clerk-stenographer; Dean Clark, laboratory assistant; and J. M. Shippee, expert laborer. Drafting; darkroom work; typing of field notes, specimen catalogs, other records and reports; assembling of the latter; and some of the routine processing of specimens were carried on with part-time student and other help.

Student assistants from several colleges and universities were employed on the summer survey field parties from June to September, as noted in a later section of this report. George Metcalf was added to the roster in October as field and laboratory assistant.

LABORATORY ACTIVITIES

The project field office and laboratory for the Missouri River Basin Survey are located in the Laboratory of Anthropology of the University of Nebraska, in the basement of Love Memorial Library. Additional storage space for specimens, equipment, and vehicles has been acquired at the Lincoln Municipal Airport. Selection of Lincoln as the place for the project headquarters has proved generally satisfactory; and the quarters generously made available by the university have been adequate, in general, for operations on the scale followed up to the present. Laboratory space has also been provided by the Nebraska State Historical Society.

During the early part of the year, the organization of the basic laboratory files was completed. These include site survey records, prepared in triplicate and filed for laboratory use by State, county, and reservoir, plus a reserve file. The basic site file at year's end included 443 site folders, each including a survey sheet, site catalog of artifacts and photographs, and other pertinent data. The reservoir site file consisted of 25 volumes and the reserve file of 17. The map file, which is rapidly being expanded, contains 566 reference maps of various kinds and 269 aerial photographs.

Drafting, map-making, and photographic work have gone forward steadily, although reliance has been almost wholly on part-time assistance. Three subbasin location maps, 62 individual reservoir maps, and approximately 700 reproductions of survey maps, sketches, and field-note diagrams have been prepared. Darkroom work includes the processing of 927 negatives representing 210 sites from 7 States; and preparation of approximately 2,500 black-and-white prints to illustrate reports and for other purposes. Kodachrome transparencies to the number of 180 augment the photographic record of accomplishments to date.

By the end of the calendar year, nearly 50,000 specimens had been cleaned, cataloged, and stored. These represent 580 sites in 44 reservoir areas scattered over 7 States. Shortage of laboratory help to conduct preliminary analysis, classification, and recording of specimens before they go into storage poses a major problem. Lack of a preparator for the proper handling and restoration, where feasible, of outstanding specimens is another serious handicap.

For the designation of archeological sites, and of specimens and photographs therefrom, a relatively simple code system has been adopted by the Missouri River Basin Survey. Site designations are trinomial in character, consisting of symbols for State, county, and site. The State is indicated by the first number, according to the

numerical position of the State name in an alphabetical list of the United States; thus, for example, Kansas is indicated by 14, Nebraska by 25, Wyoming by 48. Counties are designated by a 2-letter abbreviation; for example, FT for Frontier County, HN for Harlan County, CH for Charles Mix County. The county symbol is followed by another number referring to the specific site within the indicated State and county; usually, but not necessarily, this number represents the order in which the sites were reported or discovered. Specimens are marked in the laboratory with the appropriate site symbol, followed by a serial number referring to a particular object or group of closely associated objects. Photographs are similarly designated before filing. This system is an elaboration of that devised in Nebraska during the WPA archeological programs.

Up to the present time, very little has been published concerning the archeological survey in the Missouri River Basin. In accord with the memorandum of understanding between the Smithsonian Institution and the National Park Service, however, preliminary mimeographed appraisals of the archeological resources of reservoirs investigated have been furnished to the latter agency. These reports contain site location maps, brief descriptions of materials seen, and an evaluation of the remains located, together with recommendations for further action, if needed. They are distributed chiefly to the construction agencies, district and regional officials of the several Federal agencies concerned, and on a selective basis to cooperating institutions and organizations where their particular fields of interest are involved.

Thirty-two preliminary reports on archeology were issued during 1947. They include Anchor, Angostura, Box Butte, Boysen, Broncho, Canyon Ferry, Cedar Bluff, Cherry Creek, Crosby, Deerfield, Des Lacs, Devils Lake, Dickinson, Enders, Fort Randall, Glendo, Harlan County, Heart Butte, Jamestown, Kanopolis, Kirwin, Kortess, Lake Solitude, Medicine Creek, Medicine Lake, Oregon Basin, Shadehill and Blue Horse, Sheyenne, Tiber, Wray, and Yellowtail Reservoir areas, and the Lower Platte Subbasin. Included in the last-named were reports on the proposed Amherst, Buffalo Creek, Cairo, Ericson, Mullen, and Rockville Reservoir areas, all in Nebraska. Preparation of preliminary appraisals is well under way for Norton, Beaver City, Red Willow, Culbertson, Rock Creek, Buffalo Creek, Pioneer, and Bonny Reservoir areas in the Republican River Basin; for Wilson Reservoir area in the Smoky Hill Basin; and for Garrison and Baldhill Reservoirs, in North Dakota.

Two preliminary reports on paleontological survey were also issued. One covers Cedar Bluff, Glen Elder, Kanopolis, Kirwin, and Webster

Reservoir areas in the Smoky Hill River Basin, in Kansas. The other includes Enders, Harlan County, Medicine Creek, and Wray Reservoir areas in the Republican River Basin, in Nebraska and Colorado. Also in progress and nearing completion was a report summarizing paleontological survey data on 14 river basins containing a total of 68 reservoir areas.

Supplementary appraisals based on further archeological field surveys during the summer of 1947 were being prepared for Boysen, Canyon Ferry, Glendo, Oregon Basin, and Tiber. First drafts of technical reports were under way or completed for Anchor, Boysen, Devils Lake, Enders, Glendo, Jamestown, Kortess, Medicine Creek, Oregon Basin, Sheyenne, Harlan County, and Kanopolis. Since these are based on preliminary reconnaissance which, in some cases at least, will be followed up by intensive survey and excavation, their publication at this time or in the foreseeable future is not contemplated.

FIELD WORK AND EXPLORATIONS

KANSAS AND COLORADO

In northern and northwestern Kansas and northeastern Colorado, four proposed Bureau of Reclamation reservoir projects were surveyed for archeological remains by a River Basin Surveys party. The party consisted of Wesley L. Bliss and J. J. Bauxar, who were in the field on this assignment from April 24 to May 7. Projects visited included Wilson Reservoir, in the Smoky Hill Basin in north-central Kansas; Norton and Pioneer Reservoirs, in the Republican Basin in northern Kansas; and Bonny Reservoir, in the same basin in northeastern Colorado. The investigations were all of preliminary character, and in no case was complete coverage of the proposed pool area possible. Further and more intensive surveys are recommended if and when reservoir construction is undertaken.

Wilson Reservoir.—This area is located on the Saline River, in Russell County, Kans., with the dam site near the eastern edge of the county. Since the future pool area will be some 25 or 30 miles long, the 1½ days allotted to reconnaissance obviously permitted spot checking of only a very small portion. The six sites recorded thus represent but a fraction of the total to be expected when intensive survey is made.

Of the six sites recorded, three represent pictograph localities. At one, in addition to carvings of Indian origin, were found the names of William F. (Buffalo Bill) Cody and Wild Bill Hickok. The authenticity of these remains to be determined. Two other sites were

apparently occupational areas, that is, camp or village locations. At still another, a buried stratum yielded animal bones and charcoal, but no artifacts from which the nature and relationships of the horizon might be suggested. There is a possibility of some antiquity for this material, but further testing is needed.

Norton Reservoir.—This is on Prairie Dog Creek, a southerly affluent of the Republican River, in Norton County, Kans. The area to be inundated is small, but has archeological interest. Three sites were located, all characterized by quantities of worked yellow jasper and rejectage. There was no pottery on any of these, or elsewhere in the sections visited. A small depression on one site possibly indicates a former pit house.

The terrain in the reservoir area generally appears favorable for former Indian utilization. Prairie Dog Creek enters the Republican less than 35 miles to the northeast, within the Harlan County Reservoir which is now under construction by the Corps of Engineers. About the junction of the two streams are numerous sites representing not less than four pottery-making cultures of varying antiquity. A few miles east of the proposed Norton Reservoir is an aboriginal quarry from which the Indians obtained limestone for use in pipe making. All this leads to the suspicion that further and more intensive survey will disclose a number of additional archeological localities at Norton which will be affected by the proposed water-control developments.

Pioneer Reservoir.—Located on the Arikaree River in Cheyenne County, Kans., this will affect an area extending southwestward across the State line into Yuma County, Colo. A single site was found here, on the western terminus of the proposed dam axis. Insufficient material was collected from it to make possible a suggestion as to relationships to known archeological complexes of the region.

Bonny Reservoir.—This is to be on the South Fork of Republican River, in the southeastern corner of Yuma County, Colo. Though of small extent, it disclosed three sites of archeological interest. Artifacts of the Yuma horizon, an early prepottery complex, are reported to have been found on one by a local collector, and there appear to be cultural deposits remaining which would be worthy of excavation. Two other sites yielded too little material to be identifiable, even tentatively, as to people or period. No pottery was found within the future reservoir area.

NEBRASKA

An important share of the 1947 archeological field work of the River Basin Surveys went into reconnaissance and excavation in water-

control projects in Nebraska. Preliminary reconnaissance included five proposed reservoir areas in the Republican drainage in the southwestern part of the State, and six in the Lower Platte Basin in the central portion. The Republican River locations were surveyed by W. L. Bliss and J. J. Bauxar between April 24 and May 7; units visited include Beaver City, Red Willow, Culbertson, Rock Creek, and Buffalo Creek. Results of this work, other phases of which have been noted in the section on Kansas and Colorado, are presented first in the summary which follows. In the Lower Platte Basin, from May 3-12, M. F. Kivett and J. T. Hughes carried on reconnaissance at Amherst, Buffalo Creek, Cairo, Ericson, Mullen, and Rockville units. These projects are all under the Bureau of Reclamation.

In addition to the above, archeological excavations were begun at Medicine Creek when it was learned that early construction was planned by the Bureau of Reclamation. Work here was carried on from September 10 until November 9 by the River Basin Surveys, in continuation of previous excavations between July 25 and September 10 by the Nebraska State Historical Society, a cooperating agency. In this section only the later researches will be summarized; operations of the Historical Society are noted further in another place.

REPUBLICAN RIVER BASIN

Previous reconnaissance by the River Basin Surveys, together with earlier investigations by the Nebraska State Historical Society and the University of Nebraska, have shown that the Republican River watershed contains abundant, varied, and important archeological remains. From 1777 or before until the early 1800's, the Pawnee lived in one, two, or more earth-lodge villages along the Republican, where it crosses the Nebraska-Kansas State line. At one of these, in the present Webster County, Nebr., Pike visited in 1806. The area to the west contained no permanent settlements and was principally hunting range for the Pawnee, Dakota, Cheyenne, and other tribes. In earlier days, preceding arrival of white men, there were several successive occupations of the valley. Remains attributable to earth-lodge-using, semihorticultural Indians are widely scattered throughout the area, occurring westward nearly to, or perhaps beyond, the Nebraska-Colorado State line. They occur to some extent in the main valley, but are more plentiful on the tributaries. Between this occupation, estimated to have taken place during the thirteenth to fifteenth centuries, and that of the historic Pawnee, there were at least two others by peoples who made pottery and perhaps practiced horti-

culture. Still earlier was a fifth pottery-making group, the Woodland peoples, for whom there is as yet no conclusive proof of corn growing. There is also a growing body of evidence to show that much older, prepottery horizons are probably present, and that such ancient big-game hunters as the Folsom, Yuma, and perhaps other peoples as yet unrecognized or unnamed, passed through the district at various times in the remote past. In short, the east-west valley of the Republican, were its prehistory systematically and thoroughly worked out, would in all probability yield an exceptionally useful and important archeological cross section for the central plains region.

Noteworthy, too, is the fact that at several points in the valley prehistoric remains are found in buried soil zones, covered by what appear to be wind-laid deposits. Sometimes two or more such buried zones, lying one above the other, contain markedly dissimilar artifacts attributable to distinct occupations, and are separated by culturally sterile strata of varying thickness. Here is a suggestion that the successive inhabitants perhaps entered the region during climatically favorable times, only to be forced out of it toward the east during periods of deficient rainfall, which are marked by the sterile overlying dust deposits. Since it is to be expected that the archeological horizons will some day be datable in terms of our calendar, we may hope further to get some concrete indication of the time when these presumed prehistoric droughts transpired. An exceptional opportunity here awaits combined attack by archeologists, geologists, soils experts, paleontologists, and students of other disciplines.

Beaver City Reservoir.—The area here involved is on Beaver Creek, in southeastern Furnas County. Beaver Creek enters the Republican from the southwest at a point within the upstream limits of the Harlan County Reservoir, now under construction. Four sites were recorded here. All were littered with quantities of worked and unworked yellow jasper, and were closely similar to others found in Norton Reservoir immediately to the south in Kansas. There were no pottery remains, and it is impossible to suggest the age or cultural affiliations of the sites. They suggest workshops, and may be of no great antiquity.

Buffalo Creek Reservoir.—This is on Buffalo Creek, a northerly tributary of the Republican in Dundy County. The single site located was in a cultivated field, the surface of which was littered with village refuse. Some tendency toward concentration of the remains in smaller areas was noted. Pottery fragments suggest either Upper Republican or Woodland types, and there was a wide variety of stone artifacts. The site seems important enough to warrant further investigation.

Culbertson Reservoir.—Located on the Republican River in east-

central Hitchcock County, this area yielded only one site in the single day spent here. Yellow jasper artifacts and rejectage, together with the apparent absence of pottery, recall the similar localities found in Furnas County, Nebr., and Norton County, Kans. It is quite probable that additional sites occur within the future pool area.

Of historic interest in the area is Massacre Canyon, where the last engagement between the Pawnee and Ogallala Sioux took place on August 5, 1873. The burial ground of the Pawnee slain at the time will probably lie within the reservoir pool.

Red Willow Reservoir.—This is to be located on Red Willow Creek, in Frontier and Hayes Counties. Two alternate dam locations have been proposed. Five archeological sites were found, all with pottery remains. Tentatively, the ware is assigned to the Upper Republican horizon. At one place, there was evidence of a habitation structure at the edge of a cut bank. It seems probable that the area is a prolific one archeologically, and that among its prehistoric inhabitants were included several communities of settled, corn-growing peoples. Further work is recommended.

Rock Creek Reservoir.—This locality is in south-central Dundy County, on Rock Creek, a small tributary of the North (Arikaree) Fork of the Republican. It is quite small, and but a single site was found. From the fact that it is buried beneath some inches of overburden, the possibility of a moderate antiquity is suggested. No artifacts of diagnostic character were obtained, and test excavations will be necessary before any suggestions as to age, relationships, or possible importance can be made.

LOWER PLATTE BASIN

Water-control projects proposed for this subdivision include a number of localities on the Loup River and its tributaries. Most of the area, and the great majority of projects so far announced, lie north of the Platte, in a section of rolling loess hills. The headwaters of the Loup system are in the Sandhills region, but the greater part of the stream valleys flow through a fertile tract of loessial soils.

In historic times the area was controlled by Caddoan- and Siouan-speaking tribes who lived in fixed earth-lodge villages; grew corn, beans, and squash; made pottery; and practiced a variety of other arts and industries associated with a reasonably settled mode of life. Since, apparently, their earliest contact with white men, the Pawnee resided in a series of large, fortified towns along the lower Loup, centering in the present Howard, Nance, and Platte Counties, and on the nearby

reaches of the Platte. To the east, chiefly along or near the Missouri, dwelt the Omaha; upstream, also on the mainstem, were the Ponca; the Otoe and Missouri lived on the Platte below Elkhorn River and elsewhere in southeastern Nebraska. On the west, the Lower Platte Basin was hunting range for the still unidentified Padouca before 1800, and for the Dakota and other roving, nonhorticultural horse nomads after that date.

As in the Republican drainage, so here it is evident that before arrival of the tribes named above, a succession of other native peoples had lived in and traveled through the region. From the surveys here summarized, and work previously done at several localities by the Nebraska State Historical Society and the University of Nebraska, at least three earlier occupations by pottery-making and possibly or probably horticultural peoples may be recognized. These include remains attributed to one or more variants of the Woodland horizon, regarded as perhaps the earliest pottery-making peoples of the area; the Upper Republican peoples, who dwelt in small, unfortified villages of earth lodges, raised corn and beans, and otherwise left evidences of a relatively stable tenure of the land; and a still unidentified but apparently later group, the nature of whose occupation remains to be disclosed through archeological excavation. On the headwaters of the Middle and North Loup are village sites attributable to the Dismal River complex, also of fairly late date and probably of Apache or Comanche origin, but not yet identified with certainty with either of these.

The principal archeological excavations to date in the area with which we are here immediately concerned are few indeed, considering the extent and abundance of remains. They include work by the Nebraska State Historical Society on Davis Creek, in Greeley, Howard, and Sherman Counties; and on Myra Creek, in Valley County; by the University of Nebraska in Sherman County; and at various times by both organizations along the Loup River, in Howard, Nance, Platte, Colfax, and other counties along the major river valleys. Reports have been issued on the findings in Valley and Sherman Counties, and on some of the work along the Loup, but a great deal of the material remains unpublished.

Amherst Reservoir.—This is proposed for the Wood River, a small branch of the Platte, in west-central Buffalo County; the dam is to be at the south edge of the town of Amherst. The terrain is well suited to aboriginal occupancy, and the area is evidently one of considerable archeological interest. Five sites were located and recorded; all are within the proposed pool area. Three are represented by pottery

remains probably attributable to the Upper Republican period. At one of these there are shallow depressions in uncultivated ground, suggesting pit-house ruins. Two sites yielded thick, coarsely tempered, cord-roughened sherds similar to those of the Valley focus of the Woodland period. Here, as with many Woodland sites, the cultural level seems to be quite thin, but there is a possibility of pits and other underground features. One site, 25BF2, yielded sherds of both Woodland and Upper Republican types, suggesting two occupations and the possibility of stratification of cultures. The Upper Republican remains seem to show some variations from the usual run of this material, but whether the indicated differences are due to time or other factors cannot now be surmised.

Local collectors report the presence of many other sites within the reservoir area, and further intensive survey is called for.

Buffalo Creek Reservoir.—The locality here involved lies in north-central Dawson County, approximately 9 miles northwest of Lexington, on Buffalo Creek. Despite a generally favorable terrain, only one site was found. There was no pottery, and assignment to any known cultural complex is at present impossible. It is to be noted that many of the most promising terraces bore a heavy cover of prairie grass at time of the survey, and there may therefore well be other locations as yet unfound.

Cairo Reservoir.—This unit is proposed for Dry Creek, in Hall County, approximately 1 mile above Cairo. The area is small, and the topography not especially inviting from the standpoint of aboriginal occupation. No sites were found, and it appears improbable that further work will be needed, unless construction operations reveal now-unknown materials.

Ericson Reservoir.—This is proposed for Cedar River, in Greeley and Wheeler Counties, near the eastern edge of the Sandhills. Five sites were located, all within the proposed pool area. Pottery of rather distinctive character was present at all. The sherds were small, of a hard, thin ware composed of fine-textured gray paste with a small amount of grit temper. Exterior surfaces are generally plain; others have been treated with a simple carved paddle, and a few are cord-roughened. Parallel trailed lines above a sharp shoulder, and flaring rims with short diagonal incisions on the inner lip, were present. There is one strap handle with zigzag incised decoration. Projectile points are small triangular, with or without lateral notches; small scrapers and beveled-edge knives also occur.

The remains are quite similar to others excavated by the River Basin Surveys in 1946 at a village on Prairie Dog Creek, in

Harlan County Reservoir, and also to some from sites in Holt, Knox, and other counties in north-central Nebraska. At Harlan County, limited tests revealed shallow, vertical-walled storage pits usually filled with bison bones and other domestic debris. Typologically, the specimens suggest a late prehistoric or very early protohistoric complex, and one is tempted to wonder whether it may represent the trail of the Arikara or an early ancestral Skidi-Arikara group moving from northern Kansas through east-central Nebraska to the upper Missouri. If the makers of this material left lineal descendants among the known historic groups of the area, a Caddoan or possibly some Siouan people would seem the most likely possibility. This, obviously, is highly conjectural; but the problem awaiting study here would seem an interesting and important one, and the point of attack readily apparent.

Of quite dissimilar nature were a few thick, coarsely tempered, cord-roughened sherds apparently attributable to a Woodland complex.

Mullen Reservoir.—This locality is far up the Middle Loup River in northeastern Hooker County, well within the Sandhills region. The proposed dam site lies about 5 or 6 miles east of Mullen, and the reservoir will be approximately 7 miles long. Eight sites of varied age and origin were recorded. Judged by the surface collections made, four sites are attributable to the Dismal River complex, of late prehistoric or early protohistoric age, and one to a variant of the earlier Woodland culture. Another yielded a few sherds of unidentified cultural affiliations, similar to those at the majority of sites recorded from Ericson Reservoir. The remaining sites yielded only stone and bone implements, which perhaps represent still another horizon; a cache of more than 140 chipped artifacts was found eroding out of the bank at one of these.

At least two of the Dismal River sites are rather extensive, and show certain areas that would undoubtedly repay excavation. There has been virtually no excavation at sites of any horizon in the Sandhills region.

Rockville Reservoir.—This is on the Middle Loup in southeastern Sherman County, between Rockville and Loup City, and a few miles above the confluence of the Middle with the South Loup. At time of the reconnaissance, many of the more favorable terraces had been freshly plowed, and conditions were unsuited to site hunting. Nothing of archeological interest was located in the available time. It is believed, however, that further and more intensive search might be worth while if and when construction is initiated.

MEDICINE CREEK RESERVOIR

Medicine Creek Reservoir will be located on Medicine Creek, about $8\frac{1}{2}$ miles above Cambridge, in southeastern Frontier County. With public announcement during the summer of 1947 that contracts for this unit would be let within a few months, the River Basin Surveys took steps to salvage certain archeological materials threatened with early destruction. Preliminary surveys had been made here during the 1946 field season by Kivett and Shippee, who recorded 15 sites within the reservoir area. Two promising village sites, marked by potsherds, animal bones, mussel shells, stone artifacts, and rejectage, were situated on the west abutment of the proposed dam; two others, with similar evidences of relatively permanent occupation, lay on the left bank of the creek, at or very near a proposed borrow area just above the dam site. Because only very limited excavations had previously been made in the area, which seems to have been rather thickly settled in prehistoric times by Upper Republican peoples, two members of the Surveys staff were detailed to conduct investigations at and near the dam site. This work began early in September and continued until November 9; it was directed by M. F. Kivett, assisted by George Metcalf, and such local labor as was obtainable from time to time. As previously stated, the River Basin Surveys investigations in 1947 were a continuation of excavations begun on July 25 by the Nebraska State Historical Society.

Test excavations were made by the River Basin Surveys party in an occupational area, 25FT18, on the left bank of Lime Creek near its junction with Medicine Creek. A trench 15 feet wide was cut through the site from the south edge northward for 55 feet. Village debris varied in thickness from 12 inches at the south to approximately 30 inches at the north. Hearth areas consisting of burned red earth underlying ash beds were associated with shallow circular pits dug into the sterile yellow subsoil. Unworked fresh-water mussel shells, stone artifacts, and bone fragments were common throughout the fill. Stone artifacts included several small, stemmed projectile points, knives, and scrapers. A few awls and tubular beads of bone, as well as shell disk beads, were found. Pottery, though not plentiful, was of distinctive character; it included thick, cord-roughened body sherds, usually tempered with calcite, and one straight, undecorated rim fragment. The material, in general, is suggestive of the Woodland variant known as the Valley focus, from excavations by the Nebraska State Historical Society in Valley County, Nebr. The pottery shows also some characteristics of Woodland materials from Lane County, in west-central

Kansas. The present sample is small, however, and does not permit definitive conclusions.

At site 25FT39, situated on a high terrace on the right bank of Medicine Creek about 3 miles above the dam site but within the future pool area, two earth-lodge floors were cleared. Both had apparently been burned on abandonment, and contained large quantities of broken pottery. This included several restorable vessels which had been resting on the floor, bottom side up. The interior of one of these had been coated with a red film. Fragments of two human skulls came from a cache pit in house 1, and portions of another were found in a cache in house 2. Grinding slabs for crushing corn or seeds, and made of limestone, were found in both houses. In addition to the pottery, there were stone, bone, and other artifacts.

Two similar house floors and a midden area were excavated at site 25FT17, which lies atop a ridge that will be a part of the west end of the dam. House 1 yielded comparatively few artifacts, other than a representative series of potsherds of Upper Republican type. Unusual is the finding of one rim fragment with shell tempering. Two coarsely tempered, cord-roughened body sherds of apparent Woodland type, were found slightly below the house floor level, suggesting that remains of an earlier occupation may underlie the ruins of the earth-lodge village. House 2 yielded much broken pottery of Upper Republican types, as well as an abundance of bonework, including awls, bison-scapula digging tools, a fish hook, and other objects. Of interest were two ground-stone celts, as well as the usual chipped forms. A refuse area approximately 250 feet northeast of house 1 was dug, and from it was taken a good series of Upper Republican pottery, bone, and stone specimens. Another extensive refuse deposit on the slope east of house 2 was not opened.

With the work done by the Nebraska State Historical Society earlier in the season, seven house sites were opened by year's end in the lower Medicine Creek Reservoir area. All may be attributed to the Upper Republican horizon; variations from site to site may be due to time or group differences, or may represent merely inadequate sampling. Charred kernels of corn occurred at nearly all sites, which is in line with what we know of the semihorticultural practices of the people. Charred post and beam samples, and some badly decayed post sections, were collected, from which it may be possible ultimately to date the occupation.

The remains found during the above researches represent only a fraction of those that will be affected by reservoir construction. It is already obvious that not less than two periods of occupancy by pottery-

making groups are manifested, and there is good evidence that much older materials probably representing prepottery peoples are also present. The proximity of several earth-lodge village sites to the dam-construction area seems to offer an exceptional opportunity for study of one or more prehistoric communities of corn-growing Indians near the presumed western limit of aboriginal American agriculture in the Great Plains. The stripping by power machinery of the topsoil in preparation for laying of the earth dam fill may lay bare most of the former village areas, thus making possible the close scrutiny and precise mapping of most or all of the house units, storage pits, refuse deposits, and other features associated with the former human occupants. Such mapping of the community plan, combined with recovery of a large sample of the artifacts and other remains from all sections of the village, would permit a more definitive analysis of a prehistoric settlement than has yet been made in any part of the Great Plains. Such studies at two or three of the sites that will be worked over by power machinery, supplemented by limited tests at other sites in the reservoir area, are urgently recommended as a corollary to the actual dam-construction program.

It should be remembered that some of the prehistoric sites in, above, and below the future pool area, like many in other parts of the Republican River watershed, are buried beneath prehistoric dust blankets. The correlation of native occupations, as determinable by archeological methods, with the cyclical or other periods of deposition represented by the intervening or overlying soils, promises to give a sound footing for any attempts at dating prehistoric climatic fluctuations. Such problems, of course, transcend the field of archeology, and call for an interdisciplinary attack by geologists, soils experts, and other specialists, as well as by archeologists.

SOUTH DAKOTA

During the calendar year 1947, archeological work by the River Basin Surveys in South Dakota was restricted to Fort Randall Reservoir in the immediate valley of the Missouri River. The field unit was led by Paul Cooper, assisted by J. J. Bauxar, with Robert L. Hall and Warren Wittry as student helpers. The party left Lincoln on June 3 and terminated its activities during the first week in November. The first 6 weeks were devoted to a rapid survey along both banks of the Missouri from Fort Randall to Fort Thompson, to determine in a general way the nature and extent of archeological remains in the area. Beginning on July 18, limited test excavations were made,

with such added labor as was locally obtainable, at several of the more promising sites on the left bank of the stream. These included locations in the vicinity of Pease Creek and Wheeler Bridge, and above the mouth of Platte Creek, all in Charles Mix County. The rugged and roadless nature of much of the area, more than 200 miles long, was a serious obstacle, further complicated during the early stages of reconnaissance by a period of excessive rainfall.

Fort Randall Reservoir.—The reservoir under construction here is one of five large multiple-purpose projects planned by the Corps of Engineers for the mainstem in South and North Dakota. The dam site is located in Charles Mix and Gregory Counties, some 5 or 6 miles north of the Nebraska State line, 7 miles south of Lake Andes, and about 60 miles by river above Yankton, S. Dak. An earth-fill structure, it will have a crest length of nearly 2 miles and a maximum height of 160 feet above stream bed. At the planned maximum pool elevation of 1,375 feet (mean sea level), the impounded waters will back up approximately 100 miles to a point beyond the Big Bend, and will inundate 108,000 acres in Charles Mix, Gregory, Brule, Lyman, and Buffalo Counties.

The Missouri River here flows in a flat-floored trench from 1 to 2 miles wide, bordered by high bluffs which have been moderately to extensively dissected. Alluvial terraces are less common, especially along the right bank, than they are above Chamberlain. White River, entering from the west approximately 11 miles below Chamberlain, is the only major perennial tributary entering the reservoir area. Deciduous timber, chiefly cottonwood and willow, occurs on the main stream flood plain and on tributary valley floors. The bluffs and uplands, where not under cultivation, consist of prairie grasses. Small game is still moderately plentiful, but such once-abundant larger forms as bison, antelope, and elk are now extinct, and deer are nearly so.

The Fort Randall Reservoir area is surprisingly little known, archeologically speaking. Prior to the survey work summarized herein, the University of South Dakota Museum provided the River Basin Surveys with a location list of 27 known sites between Fort Randall and Fort Thompson. There appears, however, to be not one extant report of archeological investigations here, although the University of South Dakota Museum conducted important excavations in 1941 at Scalp Creek and at Ellis Creek, on the west bank of the river. This dearth of well-authenticated field data is the more remarkable in view of the strategic location of the district on the natural line of Indian travel between the Arikara-Mandan habitat on the upper

Missouri above Pierre, and the Central Plains area of Nebraska and Kansas to the south. Migration legends link with the Fort Randall district not only the early Arikara and Mandan, prior to their movements upstream, but also the Iowa, Omaha, and Ponca, who later migrated downstream, and the Teton and Yankton Dakota on their movements from east to west across the Missouri. In historic times—that is, during the latter decades of the eighteenth and early half of the nineteenth centuries—there were no permanent Indian towns in the area, then dominated by the Teton on the west and the Yankton on the east.

The present reconnaissance, by bringing to light a large number of sites previously unrecorded, demonstrates that it is only lack of sustained search and not actual lack of aboriginal remains that has made the section largely a blank on archeological maps of the Great Plains. The River Basin Surveys party located and recorded 93 sites; and since considerable sections of the river banks were not accessible in the available time, it is highly probable that a number of additional localities of archeological significance remain to be located and inventoried. Among those now known are both fortified and unfortified earth-lodge villages, stratified and unstratified occupational areas with dwellings of unknown character, mounds, burial grounds, tipping sites, and other antiquities of undetermined nature. In time, they range from those probably or certainly attributable to the recent Yankton Dakota to others, far more numerous, of the prehistoric period—a time span of perhaps 10 centuries or more. In some, there are multiple occupation levels separated by culturally sterile strata possibly indicative of climatic fluctuations, such as droughts. Artifacts, though often scanty, indicate relationships on several time levels with other peoples and cultures to the north, east, and south.

As with reconnaissance work generally, where little more than surface survey and collecting are done, so here at Fort Randall the artifacts recovered in the 1947 operations are quite limited in quantity. Furthermore, there is no established framework of human prehistory in the district, based on careful analysis of data gathered through controlled excavation and laboratory work, into which the new findings may be fitted. Thus, assignment of remains and interpretations as to culture history are not yet possible. Certain clues may be found in the presently available data, however, and it may be worth while, therefore, to note their nature briefly.

Particularly noteworthy are the results of test excavations in two mounds (39CH4) located a short distance below Wheeler Bridge on the left bank of the Missouri. This is near the western limit of

occurrence of burial mounds, found in increasing numbers farther east in the James and other lesser stream valleys, but exceedingly rare along the Missouri itself. The mounds, greatly reduced by long cultivation, were some 40 to 50 feet in diameter and less than 4 feet high, with circular outline. The larger contained evidences of a prepared floor of bluish clay. In each was found a subrectangular pit approximately 5 or 6 feet across, dug a foot or more into the underlying ground surface. Each pit contained the disarticulated bones of several individuals, presumably interred after exposure of the corpse had destroyed the softer tissues. In the larger mound, besides the suggestion of a prepared clay floor, there was evidence (pl. 1, fig. 1) of a log layer over the burial pit, and some of the leg and arm bones had been perforated near one end—features heretofore unreported from the upper Missouri and Great Plains region. There were no artifacts in association with the skeletal remains. Location of the village, if any, whose inhabitants built and used the burial mounds, is unknown.

Two miles downstream, on a small terrace at the junction of Pease Creek with the Missouri, exploratory pits and trenches disclosed remains (39CH5) attributable to two periods of occupation. In both levels pottery was present, though in small amounts only. That in the lower and earlier deposits appears to be in the Arikara tradition. Potsherds from the upper and later strata, on the other hand, differ, but their relationships are still unclear. A trash mound approximately $4\frac{1}{2}$ feet deep includes remains of both periods, thus affording an opportunity for significant and definitive stratigraphic studies. No house remains were detected, though their presence is suspected. Burials are reported to have been uncovered by road-building work on a bluff across the creek to the northwest.

Testing operations at the Oldham site (39CH7), about 1 mile above the mouth of Platte Creek, also revealed evidence of two successive occupations. The earlier, indicated in the diggings as a buried dark-gray soil stratum containing charcoal, flint chips, and animal bone, was represented by fragments of pottery with the surfaces roughened by a cord-wrapped paddle. In the upper zone, the pottery fragments either had plain surfaces or else had been treated with a grooved or thong-wrapped paddle so as to give a ridged effect. Associated with the second and later occupation were semisubterranean dwellings, two of which were cleared (pl. 2, fig. 1). Each had numerous closely spaced post molds outlining a well-defined circular floor; a narrow, formerly covered entrance passage; a central fireplace; and four primary posts supporting the main house structure. Many

of the molds yielded quantities of reddish-brown decayed wood and wood dust, some of it identified through its characteristic odor as juniper. Basically, the house type indicated is not unlike that used by the Pawnee, Arikara, and other early historic corn-growing, earth-lodge-dwelling Indians of the eastern Great Plains, though it deviates in certain particulars. Several refuse and cache pits were also opened. A ditch for defense still partially encloses the village area of perhaps 4 or 5 acres; cultivation has presumably obliterated this feature over the rest of the site. The ditch was probably built by the people who lived in the circular dwellings, and so belongs to the later occupation. One is tempted to suggest that the second and more recent occupation of the site may be attributable to the late prehistoric or early historic Arikara on their way up the river, although there is always a possibility that other tribes may have shared this particular grouping of material culture traits at one period. Further and more extensive excavation is called for.

On none of the sites tested was any evidence found of contact between Indians and white men. All, as indeed the great majority of those recorded, will be flooded or otherwise adversely affected by the reservoir and associated works.

NORTH DAKOTA

Two major water-control projects in North Dakota were surveyed for archeological remains by a River Basin Surveys field party. Marvin F. Kivett was in charge of the field work; he was assisted by Gordon F. McKenzie, John L. Essex, and Leo L. Stewart, students. From June 13 to August 19, this group made a preliminary reconnaissance in the Garrison Reservoir area, on the Missouri River above Bismarck. On August 21, activities were transferred to Baldhill Reservoir on the Sheyenne River above Valley City, where work was terminated on August 29. At both projects, construction is under way by the Corps of Engineers, and the time available for locating, recording, and salvage of archeological materials is rapidly becoming shorter.

Garrison Reservoir.—This project, one of the largest proposed or under construction for the Missouri River Basin, is in the northwestern part of the State. The dam site is on the mainstem in McLean and Mercer Counties, 55 miles northwest of Bismarck and about 15 miles south of Garrison. Here a rolled-fill earth embankment more than 2 miles long will rise 210 feet above stream bed to create an artificial lake extending upstream to a point above Williston, nearly 200 river miles distant. At the planned maximum pool elevation of

1,850 feet (m.s.l.), some 390,000 acres will be under water. Affected directly will be portions of Mercer, McLean, Mountrail, Williams, McKenzie, and Dunn Counties, and of the Fort Berthold Indian Reservation—an area equivalent to nearly half that of the State of Rhode Island.

Comparatively little is on record regarding the prehistory of this section of the Missouri. The reservoir will lie for the most part upstream from the area generally identified in historic times with such Upper Missouri village tribes as the Mandan, Hidatsa, and Arikara. In sharp contrast to numerous sites along the mainstem from Knife River to the White, where even the casual visitor may see house depressions, cache pits, fortifications, refuse mounds, and other surface traces, the remains above Garrison dam site are usually small, more or less deeply buried, and quite inconspicuous. For the Garrison Reservoir area, approximately a dozen sites were reported to the River Basin Surveys field party before it began operations. Most of these were thought to be winter villages, temporary camps, or late sites showing few of the pre-white elements of Indian culture.

Coverage by Kivett's party included areas in five counties, above and below Fort Berthold Indian Reservation. No work was possible on the Reservation, but record was made of nine sites reported to exist thereon. Areas most readily accessible by automobile received the closest attention. In all sections of the area seen, however, it is believed that further work is needed; and it is anticipated that more intensive survey, including access to the Reservation lands, will add many other sites to the present list.

Flint chips, stone, bone slivers, and other evidence of former human activity are to be found on virtually every suitable terrace throughout the area. In the 2-month survey, 70 sites and localities were recorded, most of them apparently unknown previously. Included are 59 occupational areas, 1 burial site, and 10 unclassified locations. No burial mounds were noted, but local informants report occasional burials in rock piles on some of the tipi-ring sites.

Eleven of the occupational areas consist of grouped circles of glacial boulders, 10 to 20 feet in diameter, and located usually on the bluffs and uplands above the future water level. Locally these are termed tipi rings, on the supposition that the stones were used to hold down skin tipi covers. Such sites are particularly common on the left bank of the future reservoir area between Sanish and Williston. Refuse and artifacts are usually scarce about these sites; when present, they include flint chips, occasional arrowpoints, scrapers or knives, grooved mauls, and perhaps glass beads and metal. Presence of metal

and glass suggests recency of occupation, but there is so little associated cultural material that no assignment of the sites to a known historic or other group or groups is now possible.

Indicative of a more settled mode of life are several sites similar to the ruined villages found in such impressive numbers farther down-river. These are not plentiful, but they occur both below and above the Fort Berthold Indian Reservation; others are reported to exist, as might be expected, within the Reservation boundaries. Circular depressions mark the sites of former earth-covered lodges, or of underground storage pits. Refuse is more plentiful on these sites, and includes broken pottery, worked stone, animal bones, etc. At least one such site, the Rock Village (32ME15) on the right bank just above the abandoned town of Expansion, appears to have been surrounded by a protective ditch. One of the circular depressions here was tested, disclosing a slab-lined fireplace 10 inches below the surface. Materials seem to be rather plentiful on the surface; those recovered include only articles of native workmanship—pottery, worked stone, steatite vessel fragments, animal bones, and a grooved maul. Pottery appears to be in the Mandan-Hidatsa tradition. North Dakota workers have suggested a pre-1850 Hidatsa origin for the site (pl. 4, fig. 1).

Of more recent date is another earth-lodge village (32MZ1), opposite the mouth of Little Knife River. Known as the Crow Flies High village, it is believed to have been occupied between 1868 and 1893 by the Hidatsa. Metal, glass, and other recent materials were plentiful, but there was little of native origin.

Most of the sites located and recorded by the Kivett party consist of artifact- and refuse-bearing strata covered by a few inches to several feet of wind-blown soil (pl. 3, fig. 1). Such locations, of course, are not usually apparent on the ground surface, and must be searched for along cut banks and eroded areas bordering the stream courses. They are marked by outcrops of burnt earth, ashes, charcoal, occasional hearths, flint chips, animal bone, and sometimes stone or bone artifacts. At least one site in McLean County (32ML9) was found to be stratified. On the surface were a few small smooth and simple-stamped pottery fragments; at a depth of 6 to 12 inches was a mixture of burnt earth, chips, bone, and thick, coarsely tempered potsherds with deep, broad cord impressions. Again, in a site in Mountrail County (32MN9), smooth and simple-stamped sherds occurred from the surface to a depth of 8 inches; a single projectile point was small, triangular, and side-notched. At 12 inches was found a second culture-bearing zone approximately 4 inches thick. This

yielded thick, coarsely tempered, cord-roughened sherds, together with fragments of large notched and stemmed projectile points. In this and the preceding site, the more deeply buried materials suggest a Woodland horizon, not unlike materials found under somewhat similar stratigraphic conditions in the central plains of Nebraska and Kansas.

It is not to be expected, of course, that a relatively rapid surface reconnaissance along several hundred miles of stream bank will permit definite conclusions as to relationships and significance of the materials inventoried and recorded. Nevertheless, it is clear that the Garrison Reservoir area has been inhabited by prehistoric peoples over a considerable period of time. The buried sites suggest small groups, some without pottery, others with pottery and perhaps some knowledge of horticulture. It is worth noting in this connection that at the time of first white contact, according to Will, the northern limit of aboriginal corn growing in the Missouri Valley was probably the Knife River. Kivett observes that village sites appear to have become more permanent and larger in later times, suggesting better adaptation to the rather harsh environment. To what extent the adoption or improvement of corn agriculture may have figured in this improved living is still uncertain. The soil which covers many of the sites suggests extensive wind action, perhaps correlated with decreased rainfall or prolonged drought conditions.

As to succession of occupations, it seems probable that the later sites with earth-lodge circles were left by the Mandan, Hidatsa, or Arikara, but of what period is not always certain. Some are probably late and decadent; others may possibly represent westward extensions of the vigorous village community economy flourishing farther downstream during the eighteenth century and perhaps earlier. A few pottery sites, to judge from the sherds, are of Woodland origin; their occurrence in buried zones and stratigraphically below sherd areas of apparent Mandan-Hidatsa affiliation is an interesting parallel to successions already known farther south. Some of these Woodland materials occur on buttes (pl. 3, fig. 2) and other elevated locations. Still other sites, without pottery and under several feet of overburden, suggest one or more prepottery occupations. No evidence of geologically ancient remains, that is, of Early Man, has yet been recognized in the Garrison area.

Baldhill Reservoir.—This project is under construction in east-central North Dakota, just outside the Missouri River watershed. An earth-fill dam 57 feet high by some 2,000 feet long will be erected on Sheyenne River about 11 miles above Valley City. The reservoir pool,

approximately 20 miles long, will inundate land in Barnes and Griggs Counties. Normal summer pool elevation is planned for 1,266 feet.

In the week allotted to reconnaissance at Baldhill, only a small portion of the future reservoir area was examined. Heavy vegetation doubtless obscured many traces of native activity and concealed surface evidence. Nevertheless, it is abundantly clear that the area has been occupied, probably at more than one period, by aboriginal groups who left several types of remains. Ten sites, all previously unreported, were located and recorded by Kivett's party.

Six sites are occupational areas, that is, are presumed to mark areas of former domestic village activity. They occur on low terraces along abandoned stream channels, and are commonly covered by a black alluvial mantle. There are few cut banks or erosion scars where deeply buried strata can be sought. Tests on the terraces showed that some of the occupational areas have considerable pottery, bone fragments, stonework, and other cultural debris. A variety of surface treatments and other techniques is shown by the pottery, and this, with certain other lines of evidence, would seem to indicate that more than one group was in the region.

In addition to the camp or village sites, three mound groups were located. The groups consist of two to five mounds each, circular or elliptical in ground plan, 3 to 6 feet high, and 15 to 30 feet in diameter. All are on the bluffs above the proposed pool level; they will not be flooded, but are subject to vandalism by visitors, workmen, and others. Some have already been partially destroyed in this fashion. It is reported that numerous burials have been taken from some of these mounds. The River Basin Surveys party made a small excavation in one (32GG1) in Griggs County, where cultivation had brought human skeletal remains to the surface. The disarticulated skeletons of eight individuals were recovered. Their distribution suggests a cumulative process of mound growth, with burials probably added from time to time, rather than a single mass grave. There were no associated artifacts to indicate possible cultural connections.

From the limited samples of artifacts collected, most of them perforce on the surfaces of sites where the chances are good for admixture with later materials, a succession of occupations seems indicated. Some of the pottery fragments show plain unmodified surfaces; others have been roughened through application to the wet clay of a cord-wrapped paddle; still others have parallel ridges, made by treatment with a grooved paddle. There is also considerable variety in the tempering material used. The fact that different methods of surface treatment and a variety of tempering materials sometimes

occur on a single site under conditions suggesting their use by a single group, may mean that there was in this area a relatively late fusion of cultural practices in vogue among several peoples at an earlier date.

Baldhill Reservoir area, and in fact the Sheyenne Valley in general, is one of considerable archeological promise. During the historic period, Indian groups seem to have traveled from east to west across the region. A number of historically important northern plains tribes are thought to have entered the Great Plains from central Minnesota and eastern North Dakota. One such group is the Cheyenne, historically a hunter tribe, but as recently as 1770 a settled semihorticultural pottery-making people living in earth-lodge villages on the Sheyenne River. A fortified town site attributed to this tribe was excavated in 1938 near Lisbon, N. Dak., by a Columbia University-North Dakota Historical Society expedition. Historical documents or tribal traditions link with the Minnesota woodlands such other tribes as the Siouan-speaking Hidatsa, Teton Dakota, and Assiniboin. Their archeological antecedents are unknown; none have been certainly correlated with any of the several known archeological complexes so far recognized in Minnesota and adjacent regions. The valleys of the Sheyenne, Big Sioux, and James Rivers, lying athwart any route westward from Minnesota, should show traces of the passage of migrating groups. One would logically expect that a geographically intermediate region such as the Baldhill locale, a convenient stopping point for tribes on the move, might show some of the cultural readjustments made in the change from an eastern woodland to a western plains habitat.

The historic tribal movements of the area, and their archeological implications, are but one of several problems to be expected at Baldhill. Another is the matter of the earth mounds with which the region abounds. Such remains occur in great numbers in northern Iowa and Minnesota. Westward, they are found into the Dakotas in diminishing numbers, reaching the Missouri sparingly in southern South Dakota and elsewhere, but not in general occurring beyond the Coteau du Missouri. So far as known, most of these appear to be burial mounds, often with grave goods. Little in the way of field research has been contributed during the last 40 years toward the matter of age, origin, and meaning of the mounds, and their connection, if any, with the village sites of the region. It seems improbable that the mounds are all assignable to a single people or period; they may well have been constructed over a considerable interval of time, although it is true that none of those so far explored have given evi-

dence of any great antiquity. The construction of such works, often in groups of three or more, would not have been undertaken by roving bands of hunters. They suggest, rather, fairly permanent village groups. The exact relationships between the mound-building Indians of the eastern Dakotas and the historic Upper Missouri village tribes remain to be worked out.

WYOMING AND MONTANA

Approximately one-third of the Missouri River watershed lies within the borders of the present States of Wyoming and Montana. The greater portion of this section consists of short-grass plains, a continuation of the grasslands of the western Dakotas and Nebraska. On the west, about the headwaters of the Missouri and its tributaries, the grasslands abut on the Rocky Mountains with their pine forests. In central Wyoming, where the northwest-to-southeast mountain barrier is interrupted, the short-grass gives way to sagebrush plains. Throughout all this great region, deciduous trees occur almost wholly as thin straggling belts along the stream valleys, with coniferous forests on the mountain masses.

In historic times, the plains and valleys were occupied by bison-hunting, horse-using nomads. North of the Missouri were the Black-foot, Gros Ventres, and Assiniboin. On the Yellowstone were the Crow; west and south of them were the Shoshoni. In eastern Wyoming were the Teton and Ogallala Dakota, and farther south, the Cheyenne and Arapaho. For most of these, there is good evidence of relatively recent arrival in the region. Concerning the movements of the western tribes, such as the Shoshoni, little information is available for the period before about 1800; and their wanderings before the eighteenth century are largely a matter of inference and conjecture.

Incomplete archeological reconnaissance has shown that camp sites, hearth areas, tipi rings, boulder alignments, quarries, and workshop remains are widely scattered over the area. Where geologic conditions are favorable, caves, rock shelters, and pictographs occur. The sites generally are littered in varying degree with clipped-stone work and rejectage; ground stone is not common, though steatite vessels and grinding implements may be found; pottery is rare, and generally absent in the more westerly sites. An interesting, abundant, and as yet little-investigated type of remains is the bison kill, found particularly north of Wyoming and into southern Canada. More recently, with the extensive soil erosion of the recent droughts, the remains of ancient bison hunters have been coming to light in various portions of the region.

Systematic investigations have been made so far in only a few spots throughout this vast region. They have shown, nevertheless, that the archeology varies through time as well as through space; that not all the sites can be ascribed to a single period; that sites exist, both in the open and in caves, where successive occupations are represented by artifact assemblages that show significant changes from level to level; that while many of the occupations are marked only by relatively thin deposits, some occur under conditions suggestive of a very respectable antiquity; and that influences from several directions have been operative at various times in the past. With a prehistory which apparently extends backward to the time when mammals now extinct roamed the area, the problem of determining the relationships of the pre-horse bison hunters to those of post-Columbian times promises to be intriguing and far from simple.

The activities of the River Basin Surveys in the Wyoming-Montana region during 1947 were largely confined to further survey at five Bureau of Reclamation water-control projects. The party doing this work consisted of Wesley L. Bliss, Jack T. Hughes, J. M. Shippee, and H. G. Pierce. Departing from Lincoln on June 10, it operated on the following schedule: at Glendo Reservoir, Wyo., June 11 to July 2; at Boysen Reservoir, Wyo., July 3 to July 25; at Oregon Basin, Wyo., July 27 to August 11; at Canyon Ferry, Mont., August 13 to August 24; at Tiber Reservoir, Mont., August 25 to September 9; and again at Boysen from September 11 to November 6. For these units, preliminary reconnaissance has now been virtually completed, and a limited amount of testing has been done. A total of 236 sites has been located and recorded. In addition, one small cave site at Boysen has been excavated to forestall its despoliation by relic collectors.

Boysen Reservoir.—Boysen dam, now under construction, is on Big Horn River at the head of Wind River Canyon, in Fremont County, Wyo., approximately 20 miles south of Thermopolis. The crest of the structure will be 140 feet above stream bed; at normal pool, elevation 4,725 feet (m.s.l.), the reservoir will extend some 20 miles southward along the Big Horn River into Shoshoni Basin to cover an area of nearly 20,000 acres. Excepting the river valley itself, the region is mainly an arid sagebrush desert, with low rainfall, little surface water, and few springs. Timber is restricted to stands of cottonwood along the stream banks, and coniferous trees, mainly yellow pine, on the slopes of the Owl Creek Mountains.

In and near the future reservoir area, 75 archeological sites have been visited and recorded by the River Basin Surveys field parties. The sites are varied in character, and, so far as may be judged from

preliminary examination, they are almost all single-occupation sites; the one certain exception, a stratified cave deposit, was excavated.

Forty-nine sites may be described as camps and occupational areas. They vary somewhat in character of the remains present, in manner of their occurrence, and in topographic location. In general, they are marked by compact to scattered clusters of fire-blackened stones, sometimes occurring in shallow pits and intermixed with bits of charcoal, and surrounded by stone chips, flakes, spalls, occasional grinding stones, chipped artifacts, bone fragments, and similar debris of former human activity. There is no indication of structures, such as tipi rings, about the hearths, which suggests the use of brush or other highly perishable shelters. On some sites debris is relatively abundant; others yield almost none of it. Many of these sites occur in hollows among the sand dunes beside intermittent streams. (pl. 4, fig. 2).

An interesting group of sites includes thin detrital areas situated in the lee of eroded sandstone outcrops on terraces and low hills overlooking stream valleys. Here there are no stone-hearth clusters or traces of structures; burned stones are scarce; and the remains consist of chipped and broken stone, occasional projectile points, knives, scrapers, or other tools, and weathered bone fragments. Whether these remains are to be attributed to peoples other than those who dwelt in the dune areas, or alternatively indicate some sort of seasonal shift of residence, is not now apparent. Presence of an occasional glass bead or iron fragment suggests that these sandstone outcrops were used as shelters by tribes of the historic period, as probably by others long before.

Other remains may be briefly noted. Six tipi-ring sites have been found; at some, stone clusters in the center of the rings indicate the former fireplaces. Stonework and other aboriginal debris is uniformly scarce. Native quarries and workshop sites to the number of seven were located in and near the reservoir area, where quartzite cobbles or other stone materials suitable for tool making were readily available. At six locations there are human (pl. 5, fig. 1) and animal representations pecked into the face of sandstone outcrops; their age and the tribal identity of their makers are unknown. Two rock-covered burials were found in sinkholes in sedimentary rock outcrops, both with the skull missing. There were no accompanying artifacts, and the tribal or cultural identity of the deceased remains uncertain.

Particularly noteworthy among the numerous Indian sites at Boysen is Birdshhead Cave (site 48FR54), situated near the base of the Owl Creek Mountains. Within this cave (pl. 5, fig. 2), tests disclosed the

presence of several levels of aboriginal occupation. Because the deposit was of small extent and limited depth, and lay close to future developmental lines where looting would inevitably take place, complete excavation was undertaken. Excavations confirmed the first impressions of a succession of occupations, and the artifact sample, though small, suggests significant variations from level to level. If the artifacts from the successive strata can be successfully correlated with artifacts from some of the single-occupation sites in the reservoir area, it may become possible to arrange the latter in a sequential order and thus bring a measure of relative chronology into the prehistory of the locality.

Analysis of the cave materials is now under way, and the actual significance of the site awaits a full and definitive statement of the laboratory findings as well as the field data. It may be noted, however, that the cave fill consisted of a series of culture-bearing strata separated by layers of decomposed rock and dust. Ash beds and hearths, some of the latter apparently containing fire-blackened stone, were associated with the upper cultural levels. A few plainware potsherds were found on and just below the surface. Below these, but in the upper levels, were steatite vessel fragments, pieces of rabbit-hair cloth, fiber cordage, basketry, small side- and base-notched points, and a few bits of obsidian. At successively lower levels were found small triangular points, then large side-notched points, and finally "fish-tailed" points with basal notch or concavity. Charcoal occurred in abundance at all levels. Refuse animal bone was moderately plentiful, consisting mainly of rodent and artiodactyl material, with little or no bison.

Strongly suggested in all this is a late prehistoric occupancy of the cave by Indians from the Great Basin to the west rather than by Plains peoples from the east. An interesting set of problems is thus opened up as to the long-time interrelationships between two rather distinctive modes of life in the semiarid western plains. The identity of the poorly represented earlier occupants at Birdshhead Cave must remain uncertain until more work has been done at other better-yielding sites.

The charcoal from Birdshhead Cave is now being studied for dendro-chronological possibilities. Through the courtesy of Gila Pueblo, Globe, Ariz., which placed a Swedish increment borer at the disposal of the River Basin Surveys party, borings were collected from living pines on the slopes about the cave. It is yet too early to indicate the results of these examinations and the likelihood of establishing a tree-ring chronology for the locality.

Glendo Reservoir.—This unit, where preconstruction work is nearing completion, is located in northern Platte County, Wyo., approximately 45 miles west of the Nebraska boundary. The dam, 90 feet high, is to be on the North Platte River, about 7 miles southeast of the town of Glendo; the reservoir will have a length of some 12 miles and a maximum surface area of approximately 3,750 acres (elevation 4,590 feet, m.s.l.). The terrain may be described briefly as a rolling to hilly grass-covered plain, with some deciduous trees on the valley bottoms and a few small conifers on the hills and bluffs along the stream. The extensive and important aboriginal quartzite quarries known as the Spanish Diggings lie a few miles to the northeast of the proposed reservoir area.

Forty-three localities of archeological interest have been recorded in two seasons of survey at Glendo. Most of these are on terraces or low bluffs near the river or its tributaries. About half are camp sites, characterized by clusters of fire-blackened stones and areas of occupational debris, such as chips, flakes, and occasional stone artifacts. Some are on the present surface; others lie buried beneath varying depths of wind-blown soils, and have been exposed by gullying or stream action. In general, they show little depth of refuse and suggest short periods of occupancy.

Six stratified sites are known. The most promising lie outside the future pool area, but close enough to be subject to extensive vandalism once reservoir construction gets under way. At one, cultural remains have been found to a depth of approximately 9 feet; they include pottery fragments from near the surface and a Folsom-like unfluted point from one of the buried strata. Another such site within the future pool area, 48PL13, showed three successive levels of occupation, at depths of 14, 30, and 60 inches below the surface. The limited artifact collections from these stratified sites strongly suggest cultural variation from level to level, but the quantity of material is insufficient to permit definition of the several complexes apparently represented. The importance of such locations lies in the clues they may give to the sequential arrangement of the numerous other sites in the area where only single occupations are indicated.

Six groups of boulder circles representing tipi rings were also located; they lie chiefly on hilltops, bluffs, and mesas back from the streams. Very little detritus occurs in association, and their age and relationships remain problematical. No caves or rock shelters are known in the reservoir area, though such sites occur in the vicinity. Two quarries were located, both on the hills above pool level. There appear to be no pictograph or petroglyph groups in the area. At one

site are a half dozen rock cairns, each approximately 1 foot high by 3 feet in diameter. Their significance is as yet unknown; similar structures have been reported in other localities in association with tipi-ring sites.

Although none of the localities now known for the Glendo Reservoir area indicates any great length or permanence of particular occupations, the evidence strongly suggests repeated use of the area by various peoples throughout a long period of time. Apparently, this use began in prepottery days and continued into quite recent times. Glass beads collected on the surface at one or two sites indicate habitation into the historic period, when such tribes as the Teton Dakota, Cheyenne, and others visited the district.

Oregon Basin Reservoir.—Oregon Basin is a subcircular natural depression about $4\frac{1}{2}$ miles in diameter, situated 8 miles southeast of Cody, in Park County, Wyo. Sandstone cliffs and ridges border it on the west and north, with sloping hills on the south and east. The surrounding terrain consists of rolling prairies cut by stream valleys, and barren hills. The flat central part of the basin floor, formerly a lake, will be used for storage of water brought through a 20-mile conduit from Shoshoni Reservoir. The basin floor is at an elevation of 5,100 feet; normal pool elevation will be 5,175 feet, with a surface area of about 4,000 acres.

Twenty-eight archeological sites are now on record for Oregon Basin, in and near the proposed reservoir area. They include open camp sites, rock shelters, workshops, and petroglyphs. Some are situated on the beach line of the ancient lake, others on knolls and slopes nearby, still others among rocky outcrops and along creek channels outside the basin. There is considerable variation in artifact types, and the aboriginal occupation of the Oregon Basin region undoubtedly goes far back into the past.

The camp sites, 12 in number, consist of scattered clusters of hearth stones, on or near the ground surface, about which is commonly a litter of flint chips, spalls, cores, animal bone, and sometimes projectile points, chipped knives, scrapers, mullers, etc. The quantity of such debris varies greatly from site to site. Pottery appears to be uniformly absent. That these sites are not all from a single period is suggested by variation in form of projectile points. Occasionally these camp sites occur as dark soil zones in cut banks, with burnt rocks, charcoal, and other refuse intermingled. One is situated near a spring on the west side of the basin, and is overlaid by 4 to 6 feet of alluvium; others appear to be weathering out from under sand dunes.

In the sandstone cliffs and overhangs which partially surround the

basin are at least six shelters (pl. 6, fig. 1) formerly used by Indians. In one, the fill containing traces of human activity is more than 10 feet deep; it consists partly of occupational debris, partly of wind-blown sand, and partly of material weathered from the overhanging walls. Though not directly imperiled by the reservoir pool, proximity of these shelters to the future reservoir makes their destruction by relic hunters almost inevitable.

Quarry workshops consist of areas littered with cores, spalls, flakes, and blanks; one was found to the north, another to the south, of the proposed reservoir area. Pictographs occur on cliffs outside the basin.

Canyon Ferry Reservoir.—Canyon Ferry Reservoir, a multiple-purpose project, will be located on the Missouri River in west-central Montana. The proposed dam site is in Lewis and Clark County, approximately 15 miles east of Helena. From this point, the dam, a concrete structure 175 feet high, will create a lake 24 miles long, extending southward into Broadwater County and covering an area of 35,000 acres at normal pool (elevation 3,800 feet, m.s.l.). The reservoir site is a broad, fertile valley lying between the Big Belt Mountains to the east and the Elkhorn Mountains to the west. There are numerous sloughs marking former river channels. A wide sloping tableland between river and mountains has been cut at its river front into high steep bluffs. Deciduous trees occur on the valley bottom, with conifers dominating the mountain slopes; otherwise, where not under cultivation, the land is in grass.

Thirty-three sites have been located by the River Basin Surveys in and near the future reservoir area. They are generally situated on terraces near the streams, or on the bluffs. Seventeen are camp sites or occupational areas, marked by quantities of chips, flakes, fire-blackened rocks, stone hearths, and occasional stone artifacts. Some lie on the present ground surface; others occur as detritus-laden strata buried by a few inches to as much as 3 feet of alluvial or wind-deposited soils. None suggest anything other than a short period of occupancy. The stone-hearth camp sites tend to occur on the flats.

Tipi rings also occur, sometimes in association with stone hearths. The rings here are rather small, seldom more than 10 to 15 feet in diameter. They may be closely grouped or widely scattered, but seem to be rather more plentiful on the higher bluffs than on the terraces or valley floors. Many of the rings have been partly destroyed or are almost buried by sod and wind-blown sand. Stone hearths occur sometimes within, sometimes outside, the rings. Artifacts and cultural detritus are very scarce in the vicinity of the tipi rings.

No caves, quarries, or workshops were located in the reservoir area.

Poorly preserved paintings in red ocher were found on rock walls outside the future pool area, in localities that will doubtless lead to destruction by vandalism.

The limited sample of artifact material recovered consists mainly of stonework. Quartzite predominates, but there are chips of chalcidony, jasper, obsidian, etc. Projectile points, knives, scrapers, and other implements are found occasionally on the surface. No pottery was noted at any of the locations.

Outside the pool area are several sites of considerable promise. At least one of these is said to have yielded points and blades suggestive of certain types of early stone industry. It is not unlikely that the occupation of the region here has been intermittent since the days of the paleo-Indian. Further investigation will be necessary before the variant types of points and other artifacts collected sparingly on the shallow camp sites and elsewhere can be arranged in a temporal sequence.

Tiber Reservoir.—The proposed Tiber Reservoir, for irrigation purposes, is on the Marias River in Toole and Liberty Counties, Mont. The dam site is in Liberty County, 12 miles south of Tiber, and approximately 45 miles above the confluence of the Marias with the Missouri. The dam is planned for a height of 185 feet; it will create a reservoir some 26 miles long, with a surface area of 17,000 acres at normal pool (elevation 2,992 feet, m.s.l.). The terrain is a flat, grassy plateau, cut by small gullies and dropping abruptly into the valley of the Marias. Steep bluffs line the stream at many points. Cottonwood and willow are found on the bottoms along the stream banks; sagebrush covers some of the flats and terraces; grass is characteristic of most of the area.

Fifty-three archeological sites have been recorded in and about the Tiber Reservoir area. Most of them fall in one or another of three major categories: buried sites in the river terraces, surface sites on the river terraces, and tipi rings generally located on the bluffs overlooking the river valley. The buried sites obviously precede those on the surface of the terraces; the latter may precede the tipi rings, but of this there is still no definite proof.

The buried sites are exposed in cut banks where lateral erosion by the Marias is removing old river terraces. Hearths, some of them apparently consisting of shallow pits filled with fire-cracked stones, ash, charcoal, and blackened earth, and associated with refuse animal bone, flint chips, flakes, and scattered bits of charcoal are to be found at depths of 1 to 23 feet below the terrace surfaces. Some of the overlying fill suggests river deposition, presumably by the stream in flood;

elsewhere, alluvial deposits derived from coulees heading in the bordering bluffs seem indicated. Unfortunately, there is at present no way to judge the rate of this deposition. That no great length of time is necessarily involved is suggested by the finding of blue glass beads and trade iron associated with an ash-filled hearth at site 24TL17, about 10 miles southeast of Shelby, on a habitation level buried beneath 12 to 18 inches of river silts on which stands a scattering grove of large cottonwoods. Despite the rather impressive depth of overburden, it is possible that the rate of deposition in many cases may have been high. Few artifacts were recovered in the survey operations at these sites. That many, perhaps most, are prehistoric, is probable; that any now known can be regarded as paleo-Indian is very doubtful.

Surface sites on the river terraces consist characteristically of clusters of fire-cracked stones, generally not associated with tipi rings, but with small quantities of worked stone and rejectage scattered in the general vicinity. Many of the hearths are partially buried, and one is tempted to wonder whether, given the proper combination of topographic and climatic factors, these sites would not resemble the buried ones in most particulars. Here the artifact inventory from the two kinds of sites may well be definitive; but such inventories can be made only after far more intensive investigations than have so far been practicable.

Tipi-ring sites occur in great numbers in the Tiber area. They seem to be most common on the plateau-like bluff tops overlooking the river valley (pl. 7, fig. 2), and are less frequently met with on the terraces. Associated with some of these are small piles of stone, usually circular in outline and about 5 feet in diameter. Tests in two of these piles disclosed small unidentifiable fragments of bone beneath them, but no satisfactory evidence that the underlying soil had ever been disturbed. Their purpose remains conjectural. It is possible that the tipi rings and associated remains are relatively late; very little stonework occurs with them and the stones composing the circles usually lie on or very near the ground surface. No metal or glass objects were noted on these sites.

No pottery-bearing sites were noted by the River Basin Surveys field party at Tiber; and such remains appear to be absent generally from the area.

A site of very considerable interest is a bison kill, 24LT22, located about 5 miles from the proposed dam site and somewhat above full pool level. It is in a shallow forked draw, where the animals were apparently ambushed, perhaps with the aid of log or brush barricades

or partial enclosures. Extensive pitting has been done by relic collectors. In these pits and in test excavations by the River Basin Surveys party, the soil contains partly burnt and decomposed bison hair, hooves, and bones, charcoal, ash, and fire-broken stones. The tests also showed that this material occurs in two, three, or more levels separated and capped by thin strata of culturally barren soil. The observed thickness of deposit varies from 1 foot upward, with the deepest bone layer noted at approximately 30 inches; greater depths have been reported by local collectors. Numerous small projectile points, mostly triangular in form with a single pair of side notches, were recovered. There is some evidence that significant type differences may exist between the points from various parts of the kill area and also between those from different levels. Local reports that "post holes" have been noted from time to time, if correct, suggest the use of corrals or barricades.

PALEONTOLOGY

The Missouri River Basin has long been noted among scientists for the wealth and variety of its paleontological resources. Systematic collecting of the remains of extinct animals and plants began with Hayden's geological survey of the Nebraska Territory in the middle of the nineteenth century. In the past 90 years, field parties from many museums and institutions have been successfully at work in numerous widely scattered localities. It has been estimated that three-fourths of the fossil materials in several of the larger museums of the nation were gathered in the Missouri River watershed.

The extraordinary richness of the Basin in this respect is due to its vast extent, its varied topography, and the long span of geologic time revealed thereby. At one place or another, the processes of uplift, deposition, and erosion have brought to light exposures of nearly all the geologic periods from Paleozoic times to the Recent. In these exposures are to be found a great variety of plant fossils, as well as vertebrate remains ranging from fishes through reptiles, including such spectacular giants as the *Brontosaurus* and the *Diplodocus*, to birds and mammals.

In order to meet its commitments to the National Park Service and the construction agencies with respect to the possible effect of water-control projects on paleontological resources, the River Basin Surveys added a paleontologist to its professional staff early in 1947. In this capacity, Dr. T. E. White arrived at the Lincoln headquarters of the Missouri Valley project on April 29 and prepared for immediate field work.

From May 2 to May 8 Dr. White visited seven proposed reservoir areas in the Lower Platte Basin in north-central Nebraska, including Amherst, Brewster, Buffalo Creek, Cairo, Ericson, Mullen, and Rockville. Fossil remains were found only in Mullen, and these were reworked material of no scientific interest. On May 13, a reconnaissance of the Smoky Hill and Republican Basins in southwestern Nebraska, northern Kansas, and northeastern Colorado was begun; by June 6, 19 reservoirs had been visited. These included Beaver City, Buffalo Creek, Culbertson, Enders, Harlan County, Medicine Creek, Rock Creek, and Red Willow Nos. 1 and 2, in Nebraska; Cedar Bluff, Glen Elder, Kanopolis, Kirwin, Norton, Pioneer, Webster, and Wilson, in Kansas; and Bonny and Wray, in Colorado. On the basis of material seen and the exposures available, more extended investigations were recommended for Beaver City, Bonny, Cedar Bluff, Enders, Harlan County, Medicine Creek, and Red Willow Nos. 1 and 2.

From June 13 to June 28 Dr. White examined the proposed Glendo Reservoir area in the North Platte Basin in Wyoming; Angostura and Deerfield in South Dakota, and Edgemont and Keyhole in Wyoming, all in the Cheyenne River Basin; Bixby and Green Grass, in the Moreau River Basin, and Blue Horse and Shadehill, in the Grand River Basin, all in South Dakota; Dickinson and Heart Butte, in the Heart River Basin, Cannon Ball in the Cannonball Basin, and Broncho, on the Knife River, all in North Dakota. Further work was recommended at Edgemont and Blue Horse. For most of the others, suitable geologic exposures were lacking, or the formations involved are much better exposed outside the proposed reservoir areas.

Between July 12 and 31 the following proposed reservoir projects in Wyoming and Montana were visited: Kortess, Onion Flat, Soral Creek, Du Noir, Boysen, Anchor, Badwater, Oregon Basin, Kane, Red Gulch, South Fork, Bull Creek, Triangle Park, Lake Solitude, Smith, Willow Park, and Middle Fork, in Wyoming; Little Horn, in Montana; and Yellowtail and Moorhead, each of which lies partially in both States. Anchor, Badwater, Boysen, Middle Fork, and Moorhead should be revisited for more intensive investigation.

From August 9 to September 25 the paleontological survey was extended to the following localities: Crosby, Jamestown, Sheyenne, and Souris, in North Dakota; Medicine Lake, Sunlight, Thief Creek, Hunter Mountain, Taylor, Bridger, Mission, Sweetgrass, Antelope, Newland, Stanford, Hobson, Ross, Snowy, Tiber, Wilson, Nilan, Wells, Canyon Ferry, Terry, Whitetail, Apex, Kelley, Clark Canyon, Brenner, and Landon, in Montana. Of these, Medicine Lake, Sun-

light, Mission, Brenner, Canyon Ferry, Tiber, Ross, Hobson, and Snowy appeared sufficiently promising to be recommended for further attention.

This trip was interrupted between August 20 and September 11, during which period Dr. White and his assistant excavated the skull and other skeletal parts of a dinosaur at Middle Fork Reservoir in Johnson County, Wyo. The dinosaur is from the Upper Jurassic Morrison formation, and has been identified as *Diplodocus*.

On October 7, Dr. White left Lincoln again to conduct intensive survey and fossil-collecting at Boysen. Enroute he examined paleontological collections at the Zeitner Museum, Mission, S. Dak., and made preliminary inspections of the proposed Philip and Rocky Ford Reservoir areas, respectively located on Bad River in Haakon County, S. Dak., and on the White River in Washington County, S. Dak.

The field work at Boysen terminated on November 7. Most of the collecting during this period was in the Eocene Wind River formation in the Cottonwood Creek drainage on the west side of Big Horn River. Among the specimens obtained the following may be noted, all represented by incomplete remains: a lemuroid (*Pelycodus*), a primitive tapir (*Heptodon*), an extinct mammal (*Coryphodon*), and the carapace (pl. 6, fig. 2) of a soft-shelled turtle (*Amyda*).

Prospects in this locality are believed to be very promising, and plans are for further work next spring. This would involve a more intensive reexamination of the Cottonwood Creek locale, as well as investigation of other known fossil localities in the basin area.

In summary, paleontological reconnaissance was carried out at 94 proposed reservoir areas between May 2 and November 7, 1947. Twelve of these are in intrusive granite and contain nothing of interest to paleontology. Seven are in geologic strata from which vertebrate fossils are at present unknown. At 25, the reconnaissance showed that fossil deposits will be directly affected and recommendations have been made for further studies if and when construction work is initiated. At the remaining areas, the vegetation cover precluded profitable search for fossils on the existing land surface, though the possibility remains that construction activities may in some places uncover worth-while materials.

As might be expected, the preliminary nature of most of the paleontological work to date has resulted in acquisition of relatively little exhibit or study material. Outstanding finds have been noted elsewhere in this report. A highly worth-while working knowledge of the units visited, of their geologic setting, and their paleontologic potentialities has been gained. It seems certain that intensification of this

work, with emphasis naturally on the more promising and urgent units, will add much significant new information to our knowledge of the paleontological resources of the Missouri River Basin.

FIELD WORK BY COOPERATING AGENCIES

It is gratifying to note that a number of State-supported agencies have oriented their own archeological and paleontological field research programs in order to assist in the scientific salvage operations in the Missouri River Basin. In some instances this has necessitated abandonment, or at least indefinite suspension, of plans previously formulated. Such agencies, where they have indicated a wish to participate in salvage work, have been granted letters from the River Basin Surveys head office at Washington, authorizing them to undertake researches in specified localities or at particular sites. This cooperation is on a voluntary basis and involves no distribution of Federal funds to the State agencies. Cooperating institutions and organizations provide reports on their operations at regular intervals and otherwise as requested, and summaries of these reports are transmitted by the Lincoln field office to the regional office of the National Park Service for such disposition and distribution as is necessary or advisable.

This section of the present report is based largely on data furnished by the agencies involved. Some of the sites noted have been visited by River Basin Surveys personnel while the State-supported work was under way.

MISSOURI

Because of more pressing construction schedules elsewhere, the Missouri River Basin Survey has undertaken as yet no field investigations in Missouri, where a number of water-control projects have been proposed by the Corps of Engineers. The University of Missouri, a cooperating agency, has been active in this region, with primary emphasis on high-priority projects lying outside the Missouri River watershed. Working with the State university are two other groups: the Missouri Resources Museum, at Jefferson City, and the Missouri Archeological Society. Active direction of the field work has been in the hands of Carl Chapman, of the university.

The archeological salvage program in this State has been, and is, of particular interest in that it demonstrates the usefulness of a coordinated effort by professionals and nonprofessionals. The State university has acted as a directing agent and a clearinghouse for information and planning. Technical advice and suggestions, and in many

cases direct assistance in the field, have been offered to members and local chapters of the Missouri Archeological Society; the latter, in turn, have reported to the university the results of their field investigations. As requested, these data have been placed at the disposal of the River Basin Surveys to assist in preparation of reports and recommendations to the National Park Service and the construction agency.

Of the several Corps of Engineers projects proposed for the Missouri River watershed in Missouri only Pomme de Terre Reservoir was surveyed in 1947. This is located on the Pomme de Terre River, a southerly tributary of the Osage. A joint survey here by the University of Missouri and the Ozarks Chapter, Missouri Archeological Society, disclosed the location of 25 sites of archeological interest. These include open camp sites, stone cairns or graves, and caves or rock shelters containing evidence of former human occupation. Pottery was found at only one site; its apparent absence from the others, together with the types of stone artifacts noted, suggests that a rather lengthy period of habitation by prepottery peoples may be represented. It is noteworthy that one of the earliest records in North America of human artifacts associated with bones of extinct Pleistocene mammals was made by Albert Koch in 1840, only a few miles downstream from the proposed Pomme de Terre dam site. Thus, despite the brief time devoted to survey in 1947 in this reservoir area, it seems clear that antiquities of considerable promise will be affected and that a close watch will have to be maintained while construction is in progress.

In addition to Pomme de Terre, investigations were carried on in 1947 at Joanna Reservoir, on Salt River in northeastern Missouri; at Clearwater Reservoir, on the Merrimac River in eastern Missouri, and at Bull Shoals Reservoir, now under construction on White River in the southwestern part of the State. Numerous sites have been located and recorded, and at Bull Shoals a camp site and a rock shelter, both stratified, were excavated. As elsewhere in the Basin, so in Missouri it is evident that a wide range in time and a variety of remains from several different periods will be directly affected by the water-control program. It is the intention of the agencies active in this area to continue the salvage operations.

NEBRASKA

In Nebraska, the Smithsonian Institution has cooperative agreements for archeological work with the Nebraska State Historical Society and the Laboratory of Anthropology, University of Nebraska,

and for paleontological work with the University of Nebraska State Museum. All these State agencies conducted field work, in varying degree, during 1947.

The Nebraska State Historical Society carried on archeological excavations at Medicine Creek Reservoir from July 25 to September 10. This work was under the personal supervision of A. T. Hill, director of the museum, who was assisted by students and local workmen. Excavations were made chiefly at two sites near the proposed location of the dam, with test work at several other points in the future reservoir area. Near the west end of the proposed dam axis, on site 25FT16, the floors of two rectangular, semisubterranean earth lodges were uncovered. The floors were approximately 30 feet long, slightly less in width, and lay at a maximum depth of about 18 inches underground. Each had a central firepit, post molds showing four primary roof supports and others showing straight walls, rounded corners, and a covered entrance passage opening to the south. From the floors and the fill immediately above, and from caches within and nearby middens outside the structures, were recovered pottery fragments, chipped- and ground-stone work, shell and bone artifacts, charred corn, and refuse animal bone. The materials can probably be safely assigned to the prehistoric semihorticultural Upper Republican horizon.

Just above the mouth of Lime Creek, some 2 miles northwest of the proposed dam site, a third house floor was opened at site 25FT28. Except in its somewhat smaller size, this differed in no important particular from those at site 25FT16. Several restorable vessels were found on the floor, along with other artifacts and miscellaneous materials, and these again indicate an Upper Republican complex, though with some variations in details.

Limited tests were made at other sites in the locality. The materials collected and the basic field data were placed at the disposal of the River Basin Surveys office at Lincoln for processing and study. As indicated elsewhere in this report, archeological excavations were continued in the Medicine Creek area by the River Basin Surveys after cessation of the work by the Nebraska State Historical Society.

A one-day reconnaissance of the proposed Bellwood and Shell Creek Reservoirs was made by Dr. J. L. Champe, University of Nebraska Laboratory of Anthropology, and Mr. Hill, of the Historical Society. Subsequently, rapid preliminary reconnaissance was made of the proposed Clearwater, Loretto, Davis Creek, Cushing, and Plum Creek Reservoirs in the Lower Platte Basin, by Dr. Champe in company with Dr. T. E. White, paleontologist for the River Basin Surveys.

As special consultant for the River Basin Surveys, Dr. Champe also spent approximately 1 week as observer at State-sponsored excavations on Lime Creek in the Medicine Creek Reservoir area.

The University of Nebraska State Museum carried on extensive investigations on Lime Creek, a small westerly tributary of Medicine Creek lying within the area to be flooded by the proposed reservoir. One fossil quarry and three sites where archeological materials are reported in association with fossil bones were worked. These investigations were under the supervision of Dr. C. B. Schultz and W. D. Frankforter.

The fossil quarry is attributed to the very late Pliocene period. Several new forms of extinct mammals are reported to have come from it, including the skull of a well-preserved saber-tooth cat at first pronounced by those in charge of the work to be a marsupial of South American type. Additional light is promised on paleontological problems of the Pliocene-Pleistocene transitional period, when detailed analysis of the findings here will have been made.

Of interest to archeologists no less than to paleontologists are the finds at three sites situated in the basal portions of a terrace identified by the University Museum investigators as Republican River Terrace 2 and assigned a late Pleistocene dating. At the principal locality, site 25FT₄₁, evidences of former human activity occur in a dark-gray stratum 47½ feet below the terrace surface (pl. 8, fig. 1). This presumably represents the valley floor at the time of human occupation. The overburden consists of silts and loess, the upper 17 feet of which have been correlated tentatively with the Bignell loess, thought to have been deposited during the Mankato stage of the Wisconsin glaciation. Points are said to have been found in situ; in addition, there were leaf-shaped and other blades, end scrapers, knives, fragments of a grooved sandstone "shaft-smoother," numerous flakes, spalls, cores, and miscellaneous rejectage. Worked bone and antler are also reported. These were associated with bones of some 17 mammalian forms, as well as those of reptiles, birds, and amphibians. Preliminary observations "suggest distinct differences between several of the fossil and modern forms, but positive identification must wait for further preparation and comparisons."

The full report on this important site is awaited with keen interest. Typologically, few of the artifacts seem to differ markedly from many of those found in later pottery-bearing horizons of the region. Among the individuals who have actually visited the site, there are rather marked discrepancies in interpretation as regards the apparent age and the relationships of the archeological remains. It seems obvious

that a manifestation with the potential importance indicated here should be thoroughly investigated by trained specialists in archeology, as well as by geologists, paleontologists, and soils experts. A combined attack with all interested disciplines represented would doubtless remove many of the doubts and uncertainties that now surround the findings, and would enable the site or sites to be placed in their proper geological and archeological setting.

SOUTH DAKOTA

In South Dakota, there was no formal cooperative arrangement between Federal and local agencies for scientific salvage work in 1947. Archeological investigations were carried on by State-supported agencies, however, and most of this work was in areas that will be affected by the Federal water-control program. A summary of the findings is included therefore in this report.

Field work from June 10 to September 1 was sponsored jointly by the University of South Dakota Museum, Vermillion, and the newly created South Dakota Archaeological Commission, Pierre. Funds for this work came partly from the State, and partly by private subscription. E. E. Meleen was in charge of the field operations, with W. H. Over acting in a general supervising capacity.

From June 10 to June 30, excavations were carried on at the LaRoche site, about 25 miles southeast of Pierre on the right bank of the Missouri River in southeastern Stanley County. Situated on a low terrace and marked by inconspicuous refuse-littered mounds, this site is expected to be inundated by the proposed Big Bend Reservoir. Two circular lodge sites were opened, each characterized by four center post molds, a central firepit, and a formerly covered entryway opening toward the southeast. Potsherds, and objects of chipped and ground stone, bone, horn, shell, and catlinite were recovered. Charred corncobs were quite common, predominantly of the 10-row variety. The pottery shows many similarities to that from protohistoric Pawnee village sites on the Loup River in central Nebraska, as well as to that from the upper levels of the Scalp Creek village site in Gregory County, S. Dak.

From July 1 to July 23, work was conducted at the Somers site, on a high bluff about 2 miles northwest of the LaRoche site, in Stanley County. Here numerous house pits are still visible, although the former village living level is buried beneath 54 inches or more of fine wind-blown dust. Limited manpower combined with the heavy overburden prevented more than a light sampling of the site. Two

contiguous walls of one lodge measuring 25 feet in width by 36 feet in length were uncovered, and a portion of one wall in a second. Both indicated a rectangular pit-house form, apparently with straight walls and slightly rounded corners. Well-preserved sections of cedar house posts, from which it may be possible ultimately to determine the date of occupancy, were recovered. Pottery fragments were relatively plentiful; most of the sherds have cord-roughened surfaces, and the general impression is one of close relationships to the prehistoric Upper Republican complex of Nebraska and Kansas. Other items found include bison-scapula hoes and charred cobs indicating a horticultural subsistence basis; bone fishhooks, awls, bone and shell disk beads, flakers, small, well-made notched and plain triangular projectile points, scrapers, leaf-shaped quartzite knives, and drills. Many of these items are also reminiscent of the Upper Republican horizon farther south, and a basic relationship is implied, even though the house types suggest possible eastern connections or influences. It seems safe to conclude that the Somers site represents an earlier time period and a different cultural complex from that manifested at LaRoche. At neither was there evidence of contact with Europeans.

Following work at the Somers site, operations were transferred to the Thomas Riggs site, on the left bank of the Missouri above Pierre in Hughes County. This site, which will be flooded by Oahe Dam, had been investigated briefly in 1940 by the University of South Dakota Museum and Works Progress Administration. In 1947, the excavation of a large semisubterranean lodge site begun in 1940 was completed. Rectangular in shape, this house was outlined by a double row of post molds and charred posts along each of the two longer sides and a single large post (12 inches) in the center at the rear end (east) and two at the front, one on each side of the entryway or ramp leading down onto the lodge floor. This structure was found to be 65 feet long by 36 feet wide. From the limited amount of pottery and other material gathered from the site, connections with the Mandan are suggested. These, however, are highly tentative; like the data from LaRoche and Somers, further information and more detailed analysis than has so far been possible is needed before wider relationships of the peoples represented can be suggested.

NORTH DAKOTA

In North Dakota, an archeological field session was sponsored jointly by the Department of Sociology and Anthropology, University of North Dakota, and the North Dakota Historical Society. A party

of six students, under the leadership of Dr. Gordon W. Hewes, devoted 6 weeks to the investigation of sites in proposed reservoir areas on Heart River and on the Missouri.

From June 25 to July 1 this expedition worked in the Heart Butte Reservoir area in Grant County, south of Glen Ullin. Limited excavations were made in a pottery-bearing deposit (32GT1) on the north bank of the Heart River, about 3 miles upstream from the dam site. Here, in a stratum reaching a thickness of 2 to 3 feet or more, were found traces of former occupation by a group of bison-hunting, semisedentary people, whose pottery tradition was quite similar to that of the Mandan and Hidatsa. Objects of ground stone, bone, horn, shell, wood, and other materials were absent or very scarce; chipped-stone work included end scrapers, drills, blades, and point fragments. No evidence of earth-lodge habitations, of agriculture, or of contact with white people were found. From the abundance of their bones, bison seem to have been the chief food item, but there was also considerable use of river mollusks. It is suggested that this site, previously recommended for excavation by a reconnaissance party of the River Basin Surveys, may represent a camping place occupied seasonally by hunting parties of the Mandan or Hidatsa, whose villages lay 50 or 60 miles to the east on the Missouri River.

Surveys made concurrently with the excavations located a small rock shelter (32GT5) near the dam site. From the very thin floor deposit came a few pieces of chipped chalcedony and fragments of a single pottery vessel of late Mandan-Hidatsa type. Fallen slabs in front of the shelter, underlaid by cultural debris, suggest that additional data may be buried beneath the collapsed front roof of a once deeper shelter. Upstream from the camp site was found a rather extensive deposit of bison bones, evidently representing the debris of a hunting drive or "kill." This deposit, now buried by 12 to 13 feet of overburden, was exposed for nearly 500 feet along the river bank; no artifacts were noted. On higher ground, above the future reservoir level, was found a chalcedony quarry; scattered spalls and a few chipped implements testify to the use of the material by the Indians.

From Heart River, the expedition moved to Fort Yates on the Standing Rock Indian Reservation. Excavations were undertaken in an earth-lodge village site (32SI4) 7 miles south of Fort Yates, on the right bank of the Missouri River. Like an undetermined number of others along the stream south of Bismarck, this site will be inundated eventually by the proposed Oahe Reservoir. On the basis of surface sherd collections, it had been previously ascribed by North Dakota workers to the "Archaic Mandan" horizon. Surface remains

otherwise consist of a number of bowl-like depressions varying in depth up to 3 feet or more and in diameter up to approximately 50 or 60 feet. There is no evidence of a protective ditch or embankment.

Preliminary excavations in several of the depressions disclosed ash-filled fireplaces and rather poorly defined floor levels, indicating the former presence of semisubterranean house structures. Test pits in various other parts of the site revealed food caches, secondarily used for refuse disposal by the Indians. Most of the 5 weeks spent at the location were devoted to examination of the feature represented by the largest surface depression.

Removal of the fill within the depression showed that the structure which once stood here had been subrectangular in outline, measuring approximately 35 by 65 feet. Circular discolorations in the floor marked the positions of the four rows of posts outlining the house area. A single small pole was recovered from one side, but most of the posts seem to have been removed when the structure was abandoned. From the position of the post molds, it is suggested that there was some sort of long central hall in the structure. The arrangement of one large and two small fireplaces, the scarcity of household refuse, the presence of three piles of bison bones (mostly unburned skull parts and horn cores) on the floor, and the exceptional size of the structure as compared to other depressions on the site, suggest that it may have been used primarily for ceremonial or other special purposes. Two large pots, broken but restorable, were recovered. Agriculture can be inferred from discovery of several bison-scapula hoes and a fragment of carbonized maize cob, but bison appear to have been a major dietary item. No burials were encountered, nor was there any evidence of trade contacts with white men.

Materials found during excavation include some bone tools, incised bone ornaments, two circular shell beads, numerous small end scrapers, a few side scrapers, projectile points, knives, choppers, scapula hoes, "squash knives," bison-rib beamers, a fragment of carbonized corncob, and much animal- and bird-bone refuse.

Pottery was not abundant on the site, but from some of the refuse pits and the fill of the structure excavated came a fair sample. A rather complex problem is presented. In addition to types that seem clearly in the tradition which culminated in the historic Mandan-Hidatsa wares farther upriver, there are numerous fragments that suggest borrowings from, or more direct relationships with, Upper Republican, Mill Creek, Cambria, and perhaps western or "Prairie" Hopewellian traditions. The site evidently falls somewhere in the prehistoric period of development of Upper Missouri village Indian

culture that culminated in the historic Mandan-Hidatsa complex observed farther to the north in and after the middle of the eighteenth century. Tentatively, it is suggested that the time period represented may be in the century between 1350 and 1450.

An area of several acres extent on Four-Mile Creek, about 2 miles from the Missouri, was found to be littered with bison bones eroding from an indurated clay stratum. Several flints that may represent crude tools were found in the same area, but their association with the bones is uncertain. There is a possibility that a prepottery hunting culture is represented here, but additional research is necessary to determine the true facts in the matter.

CONCLUSIONS

From the reconnaissance, intensive surveys, and limited excavations carried on through 1947, it is manifestly impossible to reach any fixed or definitive conclusions regarding broader aspects of the aboriginal history of the Missouri River Basin. It can be stated truthfully that the River Basin Surveys work to date has served mainly to indicate the magnitude and complexity of the problems involved, with some rather promising leads as to where partial answers to some of the problems may profitably be sought. Throughout the body of this brief report I have occasionally ventured opinions, tentative conclusions, and suggestions. In concluding this summary, therefore, I shall try to indicate only some of the highlights of work so far and to suggest certain additional avenues of approach to further information. Primary emphasis will be on the work of the River Basin Surveys, with which I am most intimately familiar.

Noteworthy is the fact that the sampling technique necessarily imposed on the River Basin Surveys program thus far is producing an impressive mass of information from widely scattered localities in the Missouri River watershed. Operating through 1947 mainly on the first, or reconnaissance, phase of the salvage work, we now have spot-check data on the archeological resources of approximately 50 localities, each of restricted areal extent. In each locality where remains have been found, there are indications of aboriginal occupations of diverse character; and frequently these, when appraised in the light of what is known for the general area, also give clues to the succession of native occupations. When these various now separate bits of information will have been properly classified and fitted into their appropriate place in the over-all picture, definitive conclusions may be expected to result.

In the Wyoming-Montana area, the surveys of 1946-47 have shown that a great number of sites exist and that the water-control program will adversely affect many of them. As has long been inferred on historic grounds, this was primarily a region of simple hunting and gathering economies, with no native horticulture except sporadically along the extreme eastern margin. Pottery occurs sparingly here and there—as at Glendo and Boysen, in Wyoming; and perhaps somewhat more plentifully along the valley of the Yellowstone in Montana. The so-called tipi rings, whose true purpose and significance are still obscure, are abundant and apparently highly characteristic. They occur in limited numbers in northern Colorado and extreme western Nebraska, and more frequently in the Dakotas eastward approximately to the Missouri from Fort Randall northward, but the greatest number of such sites seem to lie in Wyoming, Montana, and northward. It is possible that they correlate with a relatively late hunting occupation, perhaps partly at least involving Shoshonean peoples. Camp sites marked by clusters of fire-cracked stones and refuse, but without tipi rings or other evidences of structures, are also common, particularly in the western portions of the area. There is some reason to believe that many of these hearth sites are of some antiquity, since they appear to be weathering out of cut banks at varying depths below the present surface. Whether they represent an early Shoshonean occupation, or are pre-Shoshonean in time, or both, is uncertain.

Determination of cultural succession in this region is not easy, because of the simple nature of most of the site complexes and the comparatively low material yield from most occupational sites. That a series of peoples have successively inhabited the area, and that they have carried different cultural equipment, is already demonstrable, however, and there can be little doubt that continued intensive investigation at appropriate sites will lead to clearer definition of variations now only dimly recognizable. Of several stratified sites recorded by River Basin Surveys personnel, only one has been adequately studied. This is Birdhead Cave, in the Owl Creek Range west of Boysen dam site. Here it appears, from evidence noted elsewhere in this report, that peoples with a Great Basin type of subsistence economy rather than Plains hunters dwelt in late prehistoric times. Aside from the somewhat more advanced and more abundant remains in the upper levels, the principal differences from period to period are indicated by variations in form and size of projectile points. It seems probable that these objects, varying from well-made, triangular, side-notched forms in the later period to progressively earlier corner-notched and

then unnotched concave-based forms, may be of primary importance as a guide to the sequential arrangement of innumerable single-component sites in this largely potteryless region. There are several widely scattered sites that promise, if excavated, to yield important information on Early Man and related problems. At the other end of the time scale are sites, some of them beneath alluvial or aeolian deposits, such as in the Tiber Reservoir area on the Marias River, Montana, where glass beads and metal occur in association with well-defined hearths and occupation strata.

Brief mention has already been made of the bison kills of this region. These localities, where masses of the animals were slaughtered by being stampeded over cliffs or steep bluffs, or were perhaps ambushed in broken terrain, are widely scattered throughout Montana, Wyoming, and the western Dakotas. They seem to be particularly numerous along the stream valleys of western Montana, as in the Teton, Sun River, and adjacent areas. Many have been dug into by local collectors, who report the finding chiefly of great numbers of notched triangular projectile points among the bones. Some of the bone deposits in these kills or traps apparently cover thousands of square feet in extent and exhibit some depth, suggesting repeated use of the spot. Differences in form and size of projectile points are observable, and one suspects some stratigraphic variations that may be of chronological and developmental significance. It is highly desirable that systematic stratigraphic excavations be made in a number of these sites, to ascertain their age, length of use, and relationships to the archeological horizons represented at camp and occupational sites in the region. Very ancient, that is, paleo-Indian, remains have apparently seldom been found in these kills; and despite the suspected recency of some, iron arrowpoints and evidence of use of firearms are very rare or absent.

Rock alignments in this region, including converging rows of small boulder piles said to be sometimes associated with bison kills, also remain mostly unexplained and the period of their construction undetermined.

In the eastern portion of the Missouri River Basin, from North Dakota through South Dakota and Nebraska into northern Kansas, the River Basin Surveys have been concerned largely, but not exclusively, with the remains of semisedentary, pottery-making peoples. The remains of their former villages decrease in abundance and variety from east to west, with the largest villages and the climax of their cultural development shown along the banks of the Missouri and on some of its major tributaries. Some of these peoples, as already

noted, erected burial mounds along the stream valleys of eastern North and South Dakota.

In the Garrison Reservoir area north of Bismarck, N. Dak., the work of the River Basin Surveys has thrown light on the problem of what we may term the northwestern periphery of the Upper Missouri culture area. Here the fortified earth-lodge-village complex, so abundantly represented farther downstream, fades out; tipi rings, buried camp sites, and other vestiges of a less settled mode of life become more characteristic. Noteworthy is the stratification of cultures suggested at several sites: heavy cord-roughened sherds and large-stemmed projectile points underlying simple-stamped pottery and small triangular or side-notched points. It would seem from this that early Woodland manifestations preceded the Mandan-Hidatsa village complex in the northern Great Plains, as they do the earth-lodge-village dwellers in the Central Plains. At the moment, it does not appear that these Woodland-like remains occur to any great extent west of the Missouri River in the Dakotas, though further field work may change this impression. Sherds bearing well-made dentate stamp impressions and reminiscent of certain Illinois Valley specimens have been found at least as far west as Medicine Lake in northeastern Montana north of the Missouri. Check-stamped, simple-stamped and other sherds have been noted in the Williston district of western North Dakota. In general, what are perhaps the earlier ceramic sites in the region appear to show affiliations with the Woodland horizon of Minnesota whereas the later material is suggestive rather of village influences from the Mandan-Hidatsa area.

At Baldhill Reservoir, where the University of North Dakota plans investigations in the summer of 1948, important mound and village sites are present. Their strategic location with reference to east-to-west movements in late prehistoric and protohistoric times, and the rather strong evidences of an interplay of Woodland cultures from the Minnesota area with more distinctively Plains complexes, lends urgency to the problem of salvage and systematic study.

Farther down the mainstem in South Dakota, at Fort Randall Reservoir, further important information on the problem of Central and Northern Plains interrelationships was gathered in 1947. At several earth-lodge village sites there are strong evidences of an Upper Republican-like complex, with ceramic traits strikingly like those from the Republican Valley in southern Nebraska. Other sites exhibit pottery wares, house types, and other elements strongly reminiscent of the protohistoric Lower Loup complex in east-central Nebraska, suggesting that the Arikara may have moved northward

at an earlier date than is commonly supposed. Still earlier, presumably, are several small, scattered mound groups; one of these near Wheeler Bridge included mounds with log-covered burial pits containing disarticulated burials, perforated long bones, and other elements heretofore unreported from the Great Plains or the upper Missouri. From the limited excavations so far made in this section, it is evident that the late prehistoric and protohistoric archeology will be rather complicated, as may be anticipated from what we know of tribal movements into and through the locality from several directions. The presence of stratified sites leads to the conviction that an orderly arrangement of cultural events will be feasible when enough systematic work will have been done.

Still farther south, in the Lower Platte Basin and adjacent westerly subdrainages of the Missouri, promising data have been accumulating on several inadequately known archeological complexes of the Central Plains. Of particular interest is a series of sites represented at Harlan County, Ericson, and Mullen Reservoir areas. The pottery and some other remains show similarities to sites at Glen Elder and on White Rock Creek, in northeastern Kansas, and also to certain sites in northeastern Nebraska. The complex has not yet received careful study, but it seems to offer some promise of throwing light on such late prehistoric or protohistoric tribal movements as one would suspect for the Ponca, Kansa, and perhaps other Siouan tribes, or possibly for certain northern Caddoan peoples. Probably belonging to the same general time period, but of different tribal affiliation, are the several Dismal River culture sites that have come to light, one in Harlan County and several in Mullen Reservoir area. This complex is a little better known than the preceding one, and seems to be attributable to a late seventeenth- or early eighteenth-century Apache or possibly Comanche occupation. Clarification of the temporal and cultural position of both these complexes awaits further field work and careful laboratory analysis.

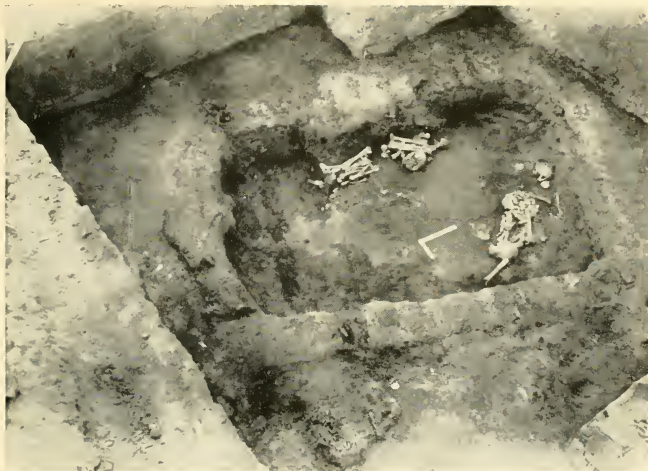
For such earlier Central Plains cultures as Upper Republican and Woodland, the 1947 field work of the River Basin Surveys has also gathered significant distributional and other data. It is becoming increasingly evident that there are variations in both which probably have developmental significance, but only further excavation of sites on a comprehensive scale can enable us accurately to define and interpret these variations. It is worth noting that the 1946 excavation by the River Basin Surveys of an ossuary on Prairie Dog Creek, near the upper end of Harlan County Reservoir, promises to compel revision of current concepts regarding burial practices of Woodland

and Upper Republican peoples, and also to contribute materially to clarification of the problem of interrelationships of these two archeological horizons. No evidence of pre-Columbian puebloan contacts with Central Plains peoples has been found.

In retrospect, it is scarcely necessary to reiterate that the surveys to date have gathered in a great quantity of useful archeological and human ecological information for many sections of the Missouri River Basin that will be directly affected by the water-control program. By comparison with the returns that might be realized through detailed excavations following up the leads now at hand, the salvage task has just begun. It has barely touched some of the potentially richest sections of the Missouri Valley. As Cooper has aptly observed in his preliminary appraisal of the archeology of Fort Randall Reservoir:

Anthropologists have for years recognized the upper Missouri as one of the richest and most promising archeological areas in North America. In historic times, an important part of the fur trade between whites and Indians was carried on at the great stockaded towns of the Mandan, Arikara, and their neighbors on the mainstem in South and North Dakota. These towns represented a comparatively advanced stage of native civilization, basically of an agricultural character, and were inhabited by what were apparently only the last of a series of people who at various times and perhaps from several directions occupied the region. Progressively simpler and less advanced peoples, who relied to a great extent on hunting, seem to have preceded the Indians first seen in the region by white men. The steps by which a highly specialized corn-bean-squash economy, adapted to the rather trying environment of the upper Missouri, evolved out of the native agricultural economies to south and east, remain to be worked out. There are suggestions that the prehistoric farmers of the area may have been beset, perhaps even displaced, from time to time, by drought, floods, and other vagaries of nature. A long and complex story of man's struggle with his environment, without the technological advantages of the white man today, thus awaits closer scrutiny. The camp sites, villages, towns, and burial places of the region represent the documents from which this story must be assembled. It is this story, rather than the mere accumulation of specimens and compiling of lists of site characteristics, which is envisaged in the archeological research program proposed.

In varying degree and with local qualifications, the above evaluation applies to all archeological remains subject to damage or destruction by the Federal water-control program in the Missouri River Basin. The challenge is obvious.



1. DISARTICULATED OR BUNDLE BURIALS IN GRAVE PIT BENEATH MOUND

Traces of log cover are visible on pit edges. Site 39CH4, near Wheeler Bridge, Fort Randall Reservoir, S. Dak. Neg. 39CH4-48.



2. BUNDLE BURIAL ON FLOOR OF GRAVE PIT

Note perforations in leg and arm bones. Site 39CH4, near Wheeler Bridge, Fort Randall Reservoir, S. Dak. Neg. 39CH4-49.



1. EXCAVATED FLOOR OF SEMISUBTERRANEAN EARTH LODGE, POSSIBLY
ARIKARA

Firepit in center, four large central and numerous small outer post holes, and vestibule entrance opening toward the southeast. Oldham Site (39CH7), Fort Randall Reservoir, S. Dak. Neg. 39CH7-9.



2. BURIED ARTIFACT STRATUM IN MISSOURI RIVER TERRACE, NEAR
CHAMBERLAIN, S. DAK.

Site 39BR11, Fort Randall Reservoir, S. Dak. Neg. 39BR11-5.



1. TESTING OCCUPATIONAL STRATUM BENEATH 5 FEET OF OVERBURDEN
Site 32MZ12, McKenzie County, Garrison Reservoir, N. Dak. Neg. 32MZ12-3.



2. BATTLE BUTTE, 6 MILES SOUTH OF EMMETT, N. DAK.

The flat summit is littered with flints, sherds, and other evidence of Indian occupancy; Missouri River at left. Site 32ML9, McLean County, Garrison Reservoir, N. Dak. Neg. 32ML9-1.



1. POST SECTION EXPOSED BY MISSOURI RIVER CUTTING INTO REMAINS OF STOCKADE SURROUNDING ROCK VILLAGE (HIDATSA?) NEAR EXPANSION TOWNSITE, N. DAK.

Site 32ME15, Mercer County, Garrison Reservoir. Neg. 32ME15-3.



2. STONE-HEARTH CAMP SITE AMONG THE DUNES ON TUFF CREEK

Site 48FR23, Boysen Reservoir, Wyo. Neg. 48FR23-2.



1. PETROGLYPHS OF UNKNOWN AGE

Site 48FR13, Boysen Reservoir, Wyo. Neg. 48FR13-1.



2. EXCAVATION OF BIRDSEAD CAVE

Site 48FR54, in the Owl Creek Range, Boysen Reservoir, Wyo. Neg. 48FR54-10.



1. LARGE ROCK SHELTER CONTAINING CULTURAL DEPOSITS AT A DEPTH OF 2 TO 3 FEET. COVERED BY STERILE DEPOSITS

Site 48PA24, Oregon Basin, Wyo. Neg. 48PA24-1.



2. DR. WHITE EXCAVATING THE CARAPACE OF A LARGE SOFT-SHELLED TURTLE (AMYDA)

This is the first well-preserved specimen of the kind ever taken from the Wind River formation, Boysen Reservoir, Wyo. Neg. 48FR65-1.



**1. FIELD PROCESSING OF SPECIMENS AT THE RIVER BASIN SURVEYS
EXPEDITION CAMP AT GLENDO RESERVOIR, WYO.**

Neg. 48PL00-6.



**2. TIPI RINGS ON BLUFFS OVERLOOKING THE MARIAS RIVER,
TIBER RESERVOIR, MONT.**

Neg. 24TL12-1.



1. DEEPLY BURIED SITE ON LIME CREEK

Figures at lower right indicate artifact- and bone-yielding stratum. Site 25FT41, Medicine Creek Reservoir, Nebr. Excavations by University of Nebraska State Museum. Neg. 25FT41-1.



2. SHELL-BEAD-ENTWINED SKELETON OF ADOLESCENT FROM PREHISTORIC BURIAL PIT

Site 14PH4, Harlan County Reservoir, Nebr. Neg. 14PH4-97. (Laboratory photograph.)



SMITHSONIAN MISCELLANEOUS COLLECTIONS
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FURTHER NEW CAMBRIAN
BELLEROPHONT GASTROPODS

(WITH ONE PLATE)

BY

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Research Associate in Paleontology
U. S. National Museum



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FURTHER NEW CAMBRIAN BELLEROPHONT
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(WITH ONE PLATE)

As the result of efforts to probe as deeply as possible into the origins of prosobranch gastropods I published some months ago a paper describing four genera of Cambrian bellerophonts (Knight, 1947). Since that time I have met with specimens of two more Cambrian species of bellerophonts, each seemingly representing still another genus heretofore unknown.

Both of these species and genera are of great interest. One, *Strepsodiscus major*, n. gen., n. sp., appears to be the earliest bellerophont yet known except the questionable bellerophont *Coreospira* Saito. Its discuslike form and deep V-shaped sinus without a slit reminds one somewhat of the Ordovician genus *Cyrtodiscus* Perner but the final half-whorl is out of contact with the others and the coil is slightly asymmetrical. Oriented as a bellerophont, the right side of some specimens protrudes slightly; oriented with this right side as "upward," the coiling would be called sinistral, a feature that may have interesting implications that will be discussed elsewhere.

Chalarostrepsis praecursor, n. gen., n. sp., resembles *Strepsodiscus major* superficially in its discuslike shape and its free final half-whorl, but it is entirely symmetrical and has a deep slit, the earliest known appearance of a slit on any gastropod. It resembles even more significantly *Tropidodiscus* Meek and Worthen (Ordovician—Devonian) since both have the discuslike shape and the deep slit, but in *Tropidodiscus* the shell is closely coiled and even involute. I regard *Chalarostrepsis* as probably the immediate forerunner of *Tropidodiscus*.

With these two, we now know six genera of quite certain Cambrian bellerophonts and two more that are probably primitive bellerophonts. *Coreospira* occurs just above or below the boundary of the Lower and Middle Cambrian. *Strepsodiscus*, new, and *Cycloholcus* Knight seem to be of Dresbachian age. *Sinuella* Knight appears to be of

late Dresbachian or early Franconian age. *Anconochilus* Knight is Franconian, and *Chalarostrepsis* new, *Owenella* Ulrich and Scofield, and *Cloudia* Knight are of Trempealeauian, seemingly in that relative order. These stages are Upper Cambrian.

That each of these six genera, except *Coreospira*, is represented by only a single known species makes it highly probable that other species will be found that will extend the recorded ranges. It is probable too that other genera are still below the horizon. Nevertheless our gradually clearing vision of Cambrian prosobranch gastropods and their occurrence in the time-stratigraphic sequence gives some basis for phyletic studies even though the results of such studies are naturally tentative.

It is to be emphasized that all but *Coreospira*, which is to be regarded as extremely primitive if indeed it is a true bellerophon, have been found only in the Upper Cambrian. The Middle and Lower divisions of the Cambrian so far as we know are destitute of definite prosobranchs and, of course, opisthobranchs and other derived groups. The asymmetrical prosobranchs, as distinct from the basically symmetrical bellerophonts, do not appear in the record until Trempealeauian time, the latest division of the Late Cambrian. There they are represented by genera that are pleurotomarians in the broadest sense such as *Dirhachopea* Ulrich and Bridge, *Taeniospira* Ulrich and Bridge, and *Sinuopea* Ulrich, and by two peculiarly sinistral non-pleurotomarian genera, *Scaevogyra* Whitfield and *Matherella* Walcott, of which I shall write again in another place. The Lower and Middle Cambrian share with later beds caplike genera, such as *Scenella* Billings, *Helcionella* Grabau and Shimer, and others, which are thought not to have arrived at the prosobranch stage, and the anomalous group of gastropodlike forms, *Pelagiella* Matthew and its allies, that may not be gastropods at all.

Although all specimens of *Strepsodiscus major* seem to show some asymmetry and always in the same sense, the species appears to be quite variable in the degree that it is developed. The holotype probably shows more pronounced asymmetry than any other specimen in the collection. Many smaller specimens are very nearly symmetrical. The other characters are so very much those of a bellerophon and more particularly of the Cyrtolitidae that the slight lateral asymmetry must be accepted, as it is in two or three other bellerophon genera. However, the asymmetry in the sinistral sense occurring so early in the record may be highly significant.

There is a possibility that *Strepsodiscus* may prove to be congeneric with *Protoscaevogyra* Kobayashi (1939, p. 286), in which case the

name would be submerged in synonymy. However, the genotype of *Protoscaevogyra* is known from a single specimen so poorly preserved that it is impossible to discover significant characters. It seems likely that *Protoscaevogyra* was applied to a sinistral example of some species of *Pelagiella*. Sinistrality seems to be a common variation in some species of that genus. I place it, along with *Proeccyliopecter* Kobayashi and *Parapelagiella* Kobayashi, as a subjective junior synonym of *Pelagiella*. It is my opinion that Kobayashi did not have opportunities to investigate thoroughly the shell morphology of *Pelagiella* and that his supposed genera are not distinct from it.

Both of the two genera erected here have a superficial resemblance to *Pelagiella*. In fact, some unknown worker had labelled the types of *Chalarostrepsis praecursor* in the National Museum as "*Pelagiella*." But although *Pelagiella* seems to have a shallow and broad peripheral emargination, it does not have a deep, V-shaped sinus as in *Strepsodiscus* nor a deep slit as in *Chalarostrepsis*. Furthermore, *Pelagiella* has only two whorls or less that expand more rapidly than in those of either. It is, of course, quite asymmetrical and, in the types of the genotype species at least, in a dextral sense.

Suborder BELLEROPHONTACEA Ulrich and Scofield, 1897

Family CYRTOLITIDAE Ulrich and Scofield, 1897

Genus STREPSODISCUS Knight, new genus

Genotype, *Strepsodiscus major* Knight, new species.

Diagnosis.—Discuslike bellerophontiform gastropods with a deep, V-shaped sinus in the anterior lip culminating sharply at the sharp dorsal crest but without a slit. The final whorl is out of contact with the coil and, at least in the only known species, there is a slight, varying degree of asymmetry in the sinistral sense.

I am placing *Strepsodiscus* in the Cyrtolitidae because of the sinus culminating at a dorsal carina or "notch keel." The light contacts of the whorls and the rather steep umbilical slopes speak likewise for that assignment. That it is a bellerophont in spite of its slightly sinistral coiling is attested by the essential bilateral symmetry of its coiling, by its anterior V-shaped sinus, and by the traillike posterior margin of the aperture.

STREPSODISCUS MAJOR Knight, new species

PLATE I, FIGURES 1A-11

Description.—A moderately large species, all observed specimens of which are to a greater or less degree asymmetrical in a sinistral

sense; the umbilical slopes commonly set off from the lateral slopes by angulations and the umbilical slope on the right side being very slightly deeper than that on the left, but in some specimens, such as the holotype, the sinistral twist is greater and the circumumbilical angulation less pronounced; whorls three in number and the final $\frac{1}{3}$ whorl free; surface features including probable pseudo-selenizone not well known but seemingly smooth except for lines of growth.

Measurements

	Diameter	Thickness
The holotype (U.S.N.M. 114277)	24.3 mm.	12.8 mm.
A figured paratype (U.S.N.M. 114278)	13.7 mm.	6.4 mm.
An unfigured paratype (U.S.N.M. 114281 a)	18.5 mm.	6.1 mm.

Hypodigm.—Approximately 150 specimens.

Remarks.—All specimens are in a light-brown calcareous sandstone with rather coarse angular sand grains. The preservation is remarkably good for so coarse a matrix. Many specimens are broken free. Great variation in relative thickness suggests that some specimens may be compressed laterally; however the matrix seems to be one that should resist compaction. The individual variation in other respects such as skewness and the angularity of the circumumbilical ridges suggests that individuals may vary in ratio of diameter to thickness too. Individuals are very abundant, as many as 15 showing on the surface of an oblong block approximately 6 cm. by 9 cm. Few individuals (only 2 out of 150) reach the size of the holotype, most of them being much smaller, narrower, and showing less skewness.

Indeed, if the larger individuals did not show the skewness to so much higher degree than the more abundant smaller ones, it might have been missed. The specimens shown on plate 1 as figures 1e-g, 1h-j, 1k-l, illustrate smaller specimens.

Occurrence.—Sawatch formation, north side of Taylor Peak, 4 miles south of Ashcraft, Colo. Collected about 100 feet above Archaean rocks in 1891 by S. Ward Loper. Associated with the numerous specimens of *S. major* were specimens of *Kingstonia loperi* Resser, *Marywillia loperi* Resser (in both cases the types) and a specimen identified by Dr. Christina Lochman Balk as "cf. *Louchocephalus*." All of these indicate a Dresbachian fauna, early Upper Cambrian, probably low in the *Crepicephalus* zone.¹

¹ Oral communication by Dr. C. L. Balk.

Family BELLEROPHONTIDAE McCoy, 1851

Genus CHALAROSTREPSIS Knight, new genus

Genotype, *Chalarostrepsis praecursor* Knight, new species.

Diagnosis.—Discuslike bellerophontiform gastropods with a shallow, narrow sinus in the anterior lip culminating in a deep, narrow slit that generates a selenizone. The final whorl is out of contact with the coil. The shell is entirely symmetrical.

I am placing *Chalarostrepsis* in the Bellerophontidae close to *Tropidodiscus* (= *Oxydiscus* Koken) which may well be derived directly from it. *Tropidodiscus* differs principally in that it is closely coiled throughout or even moderately involute.

CHALAROSTREPSIS PRAECURSOR Knight, new species

PLATE I, FIGURES 2a-c

Description.—A moderately large species of 3 or 4 whorls with sharply rounded but not angular dorsum, with the whorls of the coil barely in contact, and the last $\frac{3}{4}$ whorl free. The umbilici are, of course, widely open. The slit is almost $\frac{1}{2}$ whorl deep, narrow, and generates a convex selenizone bordered by faint striae. The aperture projects slightly behind in a skirtlike trail, then passes forward on the sides at an angle about 40° above the radius until it approaches to about one-sixth of the distance to the dorsum where it turns roundly to form the margins of the slit. The ornamentation consists of growth lines alone.

Measurements

	Diameter	Thickness
The holotype (U.S.N.M. 114282).....	11.0 mm.	4.3 mm.
A small paratype (U.S.N.M. 114283).....	5.5 mm.	?
A large imperfect paratype (U.S.N.M. 114283)....	20 mm.*	9 mm.*

* With estimates to allow for imperfections, especially in thickness.

Hypodigm.—Three specimens.

Remarks.—The only three specimens of this species known are preserved in a gray, crystalline limestone. The holotype has been largely removed from the matrix and is exquisitely preserved. It shows shape and surface features with remarkable fidelity. The slit can be seen as that adapertural portion of the dorsal crest through which the matrix within the shell was continuous before preparation, a roughened portion without a selenizone. The largest specimen is too poorly preserved for effective preparation and the smallest is too small to justify the labor. On the largest specimen the rear end of

the final whorl is separated something like $3\frac{1}{2}$ mm. from the crest of the nearest part of the previous whorl. The homologous distance on the smaller holotype is less than 1 mm. This indicates continued divergence of the final whorl.

Occurrence.—The three specimens were collected in 1889 by the late C. D. Walcott from boulders in the Lévis conglomerate near the cemetery at Point Lévis, Quebec (Walcott's locality number 115a). Species recorded as being associated are *Loganellus logani* (Devine), *Agnostus americanus* Billings, *Palaeostrophia elax* (Clark) and *Levisella* sp. These are said to indicate the *Hungaia* zone of the Upper Cambrian. The *Hungaia* zone however has not yet been placed accurately in the standard Upper Cambrian sequence of the Mississippi Valley (Rasetti, 1944, p. 231). However, it is not older than the upper third of the Franconian stage or later than the Trempealeauian. In the opinion of Dr. Christina Lochman Balk² the *Hungaia* zone is close to the upper *Dikelocephalus* zone in the Trempealeauian.

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EXPLANATION OF PLATE 1

1a-m. *Strepsodiscus major* Knight, new species.

1a-d, 1m, the holotype (U.S.N.M. No. 114277). 1a, left side view.

1b, posterior view to show skewness. 1c, anterior view showing V-shaped sinus. 1d, right side view, all $\times 1$. 1m, right side view, $\times 2$.

1e-g, a paratype (U.S.N.M. No. 114278). 1e, posterior view, $\times 2$.

1f, g, left and right side views, respectively, $\times 1$.

1h-j, a paratype (U.S.N.M. No. 114279). 1h, posterior view, $\times 2$.

1i, j, left and right side views respectively, $\times 1$.

1k-l, a paratype (U.S.N.M. No. 114280). Left and right side views, respectively, $\times 1$.

2a-c. *Chalarostrepsis praecursor* Knight, new species.

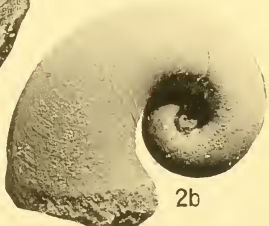
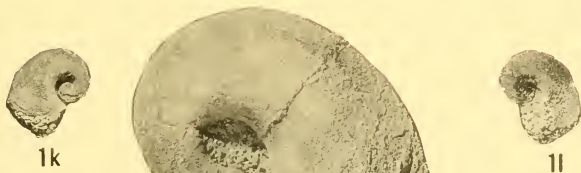
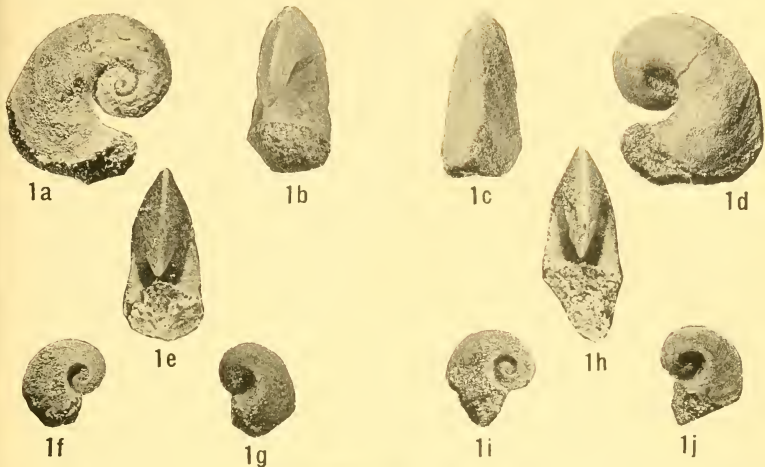
The holotype (U.S.N.M. No. 114282).

2a, oblique anterior view to show slit, $\times 4$.

2b, left side view, $\times 4$.

2c, a portion of the carina (just to right of break shown right of center on 2b) showing selenizone with lunulae, $\times 8$.

² Oral communication.



CAMBRIAN BELLEROPHONT GASTROPODS

(See explanation of plate.)



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 4

TYPE MATERIAL OF THE SPECIES OF
CLERID BEETLES DESCRIBED BY
CHARLES SCHAEFFER

BY

EDWARD A. CHAPIN

Curator, Division of Insects
U. S. National Museum



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CITY OF WASHINGTON
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TYPE MATERIAL OF THE SPECIES OF
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Curator, Division of Insects, U. S. National Museum

Between 1904 and 1921, while acting as curator of entomology of the Museum of the Brooklyn Institute of Arts and Sciences, Charles Schaeffer described 45 new species of beetles of the family Cleridae from America north of Mexico. Only in his 1921 paper on the genus *Aulicus* did he designate a single specimen as type of a species. In his early works he selected up to six specimens to stand as types of a species, and later he made no mention of the number of specimens before him upon which the description of a species was based. Occasionally it is possible for the reader to tell that one, or more than one, specimen was involved, from the remarks that follow the description.

Mr. Schaeffer's type material was originally deposited in four different collections: the collection of the Museum of the Brooklyn Institute (33 species); the Schaeffer collection, in which is incorporated the Ottomar Dietz collection (7 species); the United States National Museum (4 species); and the H. F. Wickham collection (1 species). All these collections are now in the National Museum and therefore all, or almost all, the type material is there. The writer has recently studied all this material and has designated lectotypes for all species except where the original description and discussion indicate that no more than one specimen was before the describer.

It has not been possible to recognize the type specimen of *Hydnocera nunnenmacheri* Schf. This species was described in 1908 from a single specimen bearing the same data as that given for the type material of *Hydnocera fuchsi* Schf. (described on the preceding page of the same work). In 1917 Mr. Schaeffer suppressed the former as a synonym of the latter. No specimen bearing the name label "*Hydnocera nunnenmacheri*" is to be found either in the collection of the Brooklyn Institute or in the Schaeffer collection. It is possible that upon recognizing the synonymy, Mr. Schaeffer returned the type of *H. nunnenmacheri*, minus its distinguishing label, to the type series of *H. fuchsi*.

It will be noted further on in this paper that often the type locality of a species is given as "Huachuca Mts., Arizona," and the data for the lectotype as "Palmerlee, Cochise Co., Arizona." It should be explained that Mr. Schaeffer made his headquarters for the Huachuca Mountains trip at Palmerlee and that he used the more exact locality data on the specimens themselves.

It might here be mentioned that twice Mr. Schaeffer introduced names into the literature through error. His *Clerus bioculatus* (1905, Mus. Brooklyn Inst., Sci. Bull., vol. 1, p. 154) is certainly a lapsus for *Clerus bimaculatus* Skinner, and his "var. *rufulus*" (1917, Journ. New York Ent. Soc., vol. 25, p. 131) is apparently an earlier choice of name for the variety that he described under the name of *Clerus rosmarus* var. *virginiensis*.

In the following list the species are arranged alphabetically by specific name without regard to the genus in which each was described. The generic name of the original combination follows the specific name. No attempt has been made to show the present generic assignment of any of the species.

antennata, Cymatodera

1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Three specimens, including one male, each bearing the label TYPE in the Brooklyn Museum collection; three additional specimens, without TYPE labels, in the Schaeffer collection.

Lectotype.—The male bearing Schaeffer's TYPE label, with the more detailed locality data Palmerlee, Cochise Co., Ariz., Aug. 17. U.S.N.M. No. 42533.

antennatus, Aulicus

1921. Proc. U. S. Nat. Mus., vol. 59, p. 158.

Type locality.—Palm Springs, California.

Type series.—"The male (type) is in the collection of Professor Wickham and the female (allotype) in the collection of the Brooklyn Museum."

Holotype.—The male specimen from the Wickham collection, U.S.N.M. No. 50191.

arizonica, Cymatodera undulata var.

1908. Journ. New York Ent. Soc., vol. 16, p. 130.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A

male, labeled *TYPE* by Schaeffer, and a female, both from Palmerlee, Cochise Co., Ariz., in the Brooklyn Museum collection. A male from Huachuca Mts., Ariz., in the Schaeffer collection.

Lectotype.—The male, labeled as *TYPE* by Schaeffer. Its label carries the date June 24. U.S.N.M. No. 42537.

arizonica, *Hydnocera*

1908. Journ. New York Ent. Soc., vol. 16, p. 132.

Type locality.—Huachuca Mts., Arizona.

Type series.—"In the two type specimens, male and female, * * * ." In addition to two specimens labeled *TYPE* by Schaeffer, there are 15 additional specimens in the Brooklyn Museum collection.

Lectotype.—The male bearing the *TYPE* label, U.S.N.M. No. 42540.

brevicollis, *Cymatodera*

1917. Journ. New York Ent. Soc., vol. 25, p. 130.

Type locality.—Arizona.

Type series.—"The single specimen, a female, was placed in the Dietz collection with *ovipennis*, which it superficially very much resembles."

Holotype.—The above-described specimen in the Schaeffer collection. U.S.N.M. No. 59058.

cephalica, *Cymatodera*

1908. Journ. New York Ent. Soc., vol. 16, p. 130.

Type locality.—El Taste and Santa Rosa, Lower California.

Type series.—" * * * , collected by Mr. Gustav Beyer, to whom I am indebted for the pair."

Lectotype.—The male from the above-mentioned pair, from El Taste, in the Brooklyn Museum collection. U.S.N.M. No. 42538.

dentipes, *Aulicus*

1921. Proc. U. S. Nat. Mus., vol. 59, p. 157.

Type locality.—San Diego, Texas.

Type series.—Type (male), allotype and paratypes designated in the original publication.

Holotype.—U.S.N.M. No. 23085.

femoralis, *Aulicus*

1917. Journ. New York Ent. Soc., vol. 25, p. 132.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. Two

specimens, male and female, collected at the designated type locality by F. W. Nunnemacher, in the Brooklyn Museum collection.

Lectotype.—The above-mentioned male, U.S.N.M. No. 42547.

fissipes, *Aulicus*

1921. Proc. U. S. Nat. Mus., vol. 59, p. 155.

Type locality.—Tucson, Arizona.

Type series.—Type (male) and allotype (female) designated in the original publication.

Holotype.—U.S.N.M. No. 23083.

flavosignata, *Cymatodera*

1908. Journ. New York Ent. Soc., vol. 16, p. 129.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Six specimens in the Brooklyn Museum collection and three additional in the Schaeffer collection, all labeled Palmerlee, Cochise Co., Arizona.

Lectotype.—A male from the series in the Brooklyn Museum collection, collected on Aug. 18. U.S.N.M. No. 42535.

floridana, *Chariessa*

1917. Journ. New York Ent. Soc., vol. 25, p. 133.

Type locality.—Key Largo, Florida.

Type series.—"The type specimen, a female, was collected and given me by Mr. G. Beyer." No mention of further material is made but Mr. Schaeffer, in 1918, presented the writer with a specimen, also a female, with identical data.

Lectotype.—The female in the Schaeffer collection. U.S.N.M. No. 59059.

fuchsi, *Cymatodera*

1904. Journ. New York Ent. Soc., vol. 12, p. 216.

Type locality.—Texas.

Type series.—"One male in my possession kindly given to me a few years ago by Mr. Chas. Fuchs * * * ."

Holotype.—A male specimen from Texas, in the Brooklyn Museum collection, bearing Mr. Schaeffer's TYPE label. U.S.N.M. No. 42519.

fuchsi, *Hydnocera*

1908. Journ. New York Ent. Soc., vol. 16, p. 132.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. One

specimen, apparently a male, labeled TYPE in the Brooklyn Museum collection; six specimens, males and females, in the Schaeffer collection.

Lectotype.—The specimen bearing the TYPE label, in the Brooklyn Museum collection. U.S.N.M. No. 42539.

furcatus, *Colyphus*

1904. Journ. New York Ent. Soc., vol. 12, p. 218.

Type locality.—Brownsville, Texas (San Tomas, Esperanza Ranch).

Type series.—"Four specimens in collection of the Museum of the Brooklyn Institute of Arts and Sciences." Four specimens labeled TYPE and eight others in the Brooklyn Museum collection and three in the Schaeffer collection.

Lectotype.—A male, one of the four bearing TYPE label, mentioned above. U.S.N.M. No. 42521.

granulatipenne, *Enaplum* (sic!)

1904. Journ. New York Ent. Soc., vol. 12, p. 220.

Type locality.—Brownsville, Texas (Los Boragos).

Type series.—"Types, six specimens in the Museum of the Brooklyn Institute." As there are in all eight specimens from Los Boragos in that collection, it is not possible to distinguish the six referred to in the original publication. Schaeffer had placed TYPE labels on two specimens, a male and a female.

Lectotype.—The male, selected by Schaeffer, mentioned above. U.S.N.M. No. 42525.

humeralis, *Clerus*

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 155.

Type locality.—Tulare Co., California.

Type series.—" * * * , two specimens in the collection Dietz." One specimen, apparently a female, labeled TYPE by Schaeffer, in the Brooklyn Museum collection; another specimen, also apparently female, in the Schaeffer collection.

Lectotype.—The specimen labeled as TYPE by Schaeffer, U.S.N.M. No. 42531.

laevicollis, *Cymatodera*

1908. Journ. New York Ent. Soc., vol. 16, p. 130.

Type locality.—Huachuca Mts., Arizona.

Type series.—"One female." A female specimen, without locality

label, is in the Brooklyn Museum collection. It bears the following labels: (1) TYPE; (2) Catal. No. 563; (3) *Cymatodera laevicollis* Schaeff.

Holotype.—The above-described female specimen. U.S.N.M. No. 42536.

latefascia, *Cymatodera*

1904. Journ. New York Ent. Soc., vol. 12, p. 216.

Type locality.—Fort Grant, Arizona; New Mexico.

Type series.—"Three specimens; a female in the [U. S. National] Museum collection from the first named locality, kindly given by Mr. Schwarz, another female from New Mexico and a male from Arizona without definite locality. Type No. 8163, U. S. National Museum."

Holotype.—The specimen from Fort Grant, Ariz. U.S.N.M. No. 8163.

maculicolle, *Pelonium*

1904. Journ. New York Ent. Soc., vol. 12, p. 219.

Type locality.—Brownsville, Texas.

Type series.—"Four specimens in the Museum of the Brooklyn Institute." Three males and one female, each labeled TYPE, in the Brooklyn Museum collection.

Lectotype.—A male from the above-mentioned series. U.S.N.M. No. 42524.

mesosternalis, *Lebasiella*

1908. Journ. New York Ent. Soc., vol. 16, p. 135.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. One specimen, labeled TYPE by Schaeffer, in the Brooklyn Museum collection; a second, without type label, in the Schaeffer collection.

Lectotype.—The specimen, apparently a female, in the Brooklyn collection. U.S.N.M. No. 42543.

nigrescens, *Enoplium*

1904. Journ. New York Ent. Soc., vol. 12, p. 221.

Type locality.—Brownsville, Texas (Esperanza Ranch).

Type series.—"One specimen in the Museum of the Brooklyn Institute."

Holotype.—The above-mentioned specimen, a male, U.S.N.M. No. 42526.

nigrescens, Hydnocera

1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Southern Pines, North Carolina.

Type series.—No indication of number of specimen or sex. One specimen in Brooklyn Museum collection collected May 21, 1907, and two specimens in the Schaeffer collection taken May 30, 1912, and May 17, 1915, all from Southern Pines by A. H. Manee.

Lectotype.—[Probably holotype], the specimen, a female, collected May 21, 1907, in the Brooklyn Museum collection. U.S.N.M. No. 42544.

nigrina, Hydnocera

1908. Journ. New York Ent. Soc., vol. 16, p. 134.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A single specimen in the Brooklyn Museum collection from Carr's Peak, Huachuca Mts., Ariz., July 20, and labeled TYPE by Schaeffer.

Lectotype.—[Probably holotype], the above-described specimen, apparently a female. U.S.N.M. No. 42542.

nigriventris, Aulicus

1921. Proc. U. S. Nat. Mus., vol. 59, p. 156.

Type locality.—Mexico.

Type series.—Type (male), allotype (female) and paratypes, designated in the original publication.

Holotype.—U.S.N.M. No. 23084.

niveifascia, Hydnocera

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 156.

Type locality.—Palmerlee, Cochise Co., Arizona.

Type series.—No indication of number of specimens or sex. Eight specimens, all from the designated type locality, in the Brooklyn Museum collection. One specimen was labeled TYPE by Schaeffer.

Lectotype.—The specimen labeled TYPE by Schaeffer, apparently a male, U.S.N.M. No. 42532.

nunnenmacheri, Hydnocera

1908. Journ. New York Ent. Soc., vol. 16, p. 133.

Type locality.—Nogales, Arizona.

Type series.—" * * * ", one male kindly given me by Mr. F. W.

Nunnenmacher." No specimen bearing this name was found either in the Brooklyn Museum collection or in the Schaeffer collection.

Holotype.—Lost. See introductory remarks for discussion.

obliquefasciata, *Cymatodera*

1904. Journ. New York Ent. Soc., vol. 12, p. 215.

Type locality.—Brownsville, Texas (Esperanza Ranch), from *Acacia flexicaulis*.

Type series.—"Three specimens in the Museum of the Brooklyn Institute." Four specimens in the Brooklyn Museum collection, three of which, a male and two females, bear Schaeffer's TYPE label.

Lectotype.—The male, from the above-mentioned series. U.S.N.M. No. 42517.

pallida, *Cymatodera*

1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Four specimens, two males, one female, and one of uncertain sex, in the Brooklyn Museum collection; one female in the Schaeffer collection.

Lectotype.—A male in the Brooklyn Museum collection. U.S.N.M. No. 42518.

pallipes, *Macrotelus terminatus* var.

1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality.—Brownsville, Texas.

Type series.—"The moderately large series which I have taken or raised from branches of *Acacia farnesiana* and *Acacia flexicaulis* * * * ." Four specimens, two males and two females, in the Brooklyn Museum collection and four in the Schaeffer collection.

Lectotype.—A male from the series in the Brooklyn Museum collection, U.S.N.M. No. 42534.

palmii, *Clerus*

1904. Journ. New York Ent. Soc., vol. 12, p. 218.

Type locality.—Senator, Arizona.

Type series.—"One specimen kindly given to me some years ago by Mr. Chas. Palm * * * ."

Holotype.—The specimen in the Brooklyn Museum collection from the designated type locality. U.S.N.M. No. 42522.

parviceps, *Hydnocera*

1908. Journ. New York Ent. Soc., vol. 16, p. 134.

Type locality.—Senator, Arizona.

Type series.—"One female given me some years ago by Mr. Charles Palm." One specimen in the Schaeffer collection.

Holotype.—The above-mentioned female specimen. U.S.N.M. No. 59066.

peninsularis, *Cregya*

1917. Journ. New York Ent. Soc., vol. 25, p. 132.

Type locality.—Santa Rosa, Lower California.

Type series.—No indication of number of specimens or sex. One female in the Brooklyn Museum collection and a pair, male and female, in the Schaeffer collection, all from Santa Rosa.

Lectotype.—The male specimen from the Schaeffer collection. U.S.N.M. No. 42548.

peninsularis, *Cymatodera*

1904. Journ. New York Ent. Soc., vol. 12, p. 214.

Type locality.—San Felipe, Lower California.

Type series.—"Two specimens from Mr. G. Beyer in the Museum of the Brooklyn Institute." Both specimens are male.

Lectotype.—One of the two above-mentioned specimens. U.S.N.M. No. 42516.

pinus, *Clerus*

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 155.

Type locality.—"Carr's Peak, Huachuca Mountains, Arizona, beaten from pines at an elevation of 9,000 feet."

Type series.—No indication of number of specimens or sex. Two specimens from Carr's Peak, one bearing Schaeffer's TYPE label, in the Brooklyn Museum collection.

Lectotype.—A male, bearing Schaeffer's TYPE label. U.S.N.M. No. 42530.

pusilla, *Hydnocera*

1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. Three specimens, each labeled TYPE by Schaeffer, in the Brooklyn Museum collection. Three, without such labels, in the Schaeffer collection.

Lectotype.—A male, one of the three specimens in the Brooklyn Museum collection. U.S.N.M. No. 42545.

quercus, Clerus

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 154.

Type locality.—Palmerlee, Cochise Co., Arizona, from oak.

Type series.—No indication of number of specimens or sex. A single specimen, a male, from the designated type locality, bearing Schaeffer's TYPE label, in the Brooklyn Museum collection.

Lectotype.—[Probably holotype], the above-mentioned specimen. U.S.N.M. No. 42529.

ruficollis, Monophylla

1911. Journ. New York Ent. Soc., vol. 19, p. 121.

Type locality.—Arizona.

Type series.—" * * * , the single specimen, a female in my collection, * * * ."

Holotype.—A female from Arizona, in the Schaeffer collection. U.S.N.M. No. 59060.

santarosae, Cymatodera

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 152.

Type locality.—Santa Rosa, Lower California.

Type series.—" * * * , male and female, collected by Mr. Gustav Beyer, to whom I am indebted for the pair." A pair in the Brooklyn Museum collection, which were labeled TYPE ♂ and TYPE ♀ by Schaeffer.

Lectotype.—The male from the above-mentioned pair. U.S.N.M. No. 42528.

simulans, Hydnocera

1908. Journ. New York Ent. Soc., vol. 16, p. 133.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. One specimen labeled TYPE by Schaeffer, in the Brooklyn Museum collection, together with three others, all from the designated type locality.

Lectotype.—The specimen labeled TYPE by Schaeffer. U.S.N.M. No. 42541.

subcostatus, *Clerus thoracicus* var.

1917. Journ. New York Ent. Soc., vol. 25, p. 131.

Type locality.—Enterprise, Florida.

Type series.—"Enterprise, Florida (O. Dietz). I have another specimen from New Braunfels, Texas, which agrees with the Florida specimen in the characters given above."

Lectotype.—The Enterprise, Fla., specimen, in the Schaeffer Collection. U.S.N.M. No. 59061.

tricolor, *Hydnocera*

1904. Journ. New York Ent. Soc., vol. 12, p. 219.

Type locality.—Brownsville, Texas.

Type series.—"Four specimens in the Museum of the Brooklyn Institute." Of these, one is a male, the other three are females.

Lectotype.—The male from the above-mentioned series. U.S.N.M. No. 42523.

tristis, *Hydnocera*

1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A single specimen, a male, labeled TYPE by Schaeffer, in the Brooklyn Museum collection. A second specimen in Schaeffer collection.

Lectotype.—The male in the Brooklyn Museum collection. U.S.N.M. No. 42546.

uniformis, *Cymatodera*

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 151.

Type locality.—Prescott, Arizona.

Type series.—" * * * , one male, which I owe to the kindness of Mr. Charles Fuchs, of San Francisco, Cal."

Holotype.—The above-mentioned specimen, in the Brooklyn Museum collection. U.S.N.M. No. 42527.

van dykei, *Cymatodera*

1904. Journ. New York Ent. Soc., vol. 12, p. 217.

Type locality.—California (Los Angeles Co.).

Type series.—"Two specimens kindly given to me by Dr. Van Dyke to whom this species is dedicated." A male and a female, each labeled TYPE by Schaeffer and both in the Brooklyn Museum collection.

Lectotype.—The male specimen mentioned above. U.S.N.M. No. 42520.

virginiensis, *Clerus rosmarus* var.

1917. Journ. New York Ent. Soc., vol. 25, p. 131.

Type locality.—Virginia.

Type series.—No indication of number of specimens or sex. A single specimen in the Schaeffer collection.

Lectotype.—The above-mentioned specimen. U.S.N.M. No. 59062.



SMITHSONIAN MISCELLANEOUS COLLECTIONS
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1948-1949 REPORT ON THE
27.0074-DAY CYCLE IN WASHINGTON
PRECIPITATION

BY

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(PUBLICATION 3980)

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1948-1949 REPORT ON THE 27.0074-DAY CYCLE IN WASHINGTON PRECIPITATION

By C. G. ABBOT

Research Associate, Smithsonian Institution

In Smithsonian Miscellaneous Collections¹ I have set forth an apparent cycle of precipitation at Washington associated with the sun's rotation. In 1948, for the fifteenth consecutive year, the average precipitation for predicted favorable days has exceeded the average precipitation on all other days of the year. The results for 1948 precipitation are given in table I.

TABLE I.—*Statistics of Washington precipitation, 1948*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average per day { Pfd.	0.292	0.049	0.274	0.146	0.386	0.123	0.095	0.173	0.086	0.022	0.190	0.221	0.175
Other	0.038	0.091	0.087	0.007	0.161	0.140	0.136	0.338	0.151	0.165	0.195	0.084	0.137
Ratio	7.68	0.54	3.15	20.8	2.40	0.88	0.70	0.51	0.60	0.13	0.97	2.63	1.28
Total ppt.	4.99	2.05	5.31	2.44	8.59	3.98	3.60	8.00	3.63	3.11	5.78	4.93	56.41
Normal	3.55	3.37	3.75	3.27	3.70	4.13	4.71	4.01	3.24	2.84	2.37	3.32	42.26
Percent	141	61	142	75	232	96	76	200	112	110	244	153	133

Lines 1 and 2 give the average precipitation in inches per day for preferred and all other days of the year 1948. Line 3 gives the ratio: "preferred" / other. Lines 4 and 5 give the total precipitation and normal precipitation in inches, and line 6 gives the percentage of normal precipitation falling in the several months, and in the entire year.

Preferred days had a higher average precipitation than other days in the 5 months January, March, April, May, and December, and in the year as a whole. The other 7 months went the other way, but November had almost an exact balance between preferred and other days. However, if on June 19, August 1, September 21, October 5, and November 28 precipitation had been delayed a few hours and occurred on the next following days, these 5 months would also have been favorable to the preferred days.

Statistically, the ratio: "preferred" / other is expected to be 1.42. The ratio for the 15 years ending with 1948 has actually been 1.46.

Table 2 gives the dates for 1949 when the average daily precipitation is expected to exceed the average daily precipitation on all other days of the year. In the first column are given in Roman numerals the day number of the 27 days of the cycle when higher precipitation is expected. The remainder of the table gives the actual dates in the different months which correspond to these Roman

¹ Smithsonian Misc. Coll., vol. 104, Nos. 3 and 5, 1944; vol. 110, No. 4, 1948.

numerals, in other words the "preferred days" for 1949. These preferred days should give, on the average, higher precipitation per day than all the other days of the year, but there is no high probability that precipitation will actually fall on any individual day among "preferred days," or will not fall on any individual other day.

TABLE 2.—*Predicted dates when average daily precipitation should exceed average daily precipitation for all other dates in Washington, D. C., for the year 1949*

"Preferred" cycle places	Jan.	Feb.	Mar.	Apr.	May	June
I	24	20	19	15	12	8
II	25	21	20	16	13	9
III	26	22	21	17	14	10
IV	27	23	22	18	15	11
V	1, 28	24	23	19	16	12
XII	8	4	3	26	23	19
XIII	9	5	4, 31	27	24	20
XV	11	7	6	2, 29	26	22
XVII	13	9	8	4	1, 28	24
XVIII	14	10	9	5	2, 29	25
XXII	18	14	13	9	6	2, 29
XXVI	22	18	17	13	10	6
XXVII	23	19	18	14	11	7

"Preferred" cycle places	July	Aug.	Sept.	Oct.	Nov.	Dec.
I	5	1, 28	24	21	17	14
II	6	2, 29	25	22	18	15
III	7	3, 30	26	23	19	16
IV	8	4, 31	27	24	20	17
V	9	5	1, 28	25	21	18
XII	16	12	8	5	1, 28	25
XIII	17	13	9	6	2, 29	26
XV	19	15	11	8	4	1, 28
XVII	21	17	13	10	6	3, 30
XVIII	22	18	14	11	7	4, 31
XXII	26	22	18	15	11	8
XXVI	3, 30	26	22	19	15	12
XXVII	4, 31	27	23	20	16	13

The statistical tabulation of 27-day cycles, on which table 2 is based, began January 1, 1924, and it indicated that the true cycle is 27.0074 days. In 25 years since December 31, 1923, there were 9.132 days. In 339 cycles of 27.0074 days there are 9,155.50 days, or in round numbers 23 days more than in the years 1924-1948. Hence the first day of the 340th cycle begins on January 24, 1949, as given in table 2, corresponding to Roman numeral I.

It should be emphasized that this prediction relates only to Washington, D. C.²

² This paper was finished on January 18, 1949, immediately after receipt of Weather Bureau data for December 1948.

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A PREDICTION OF WASHINGTON
TEMPERATURE 1948
(MADE JANUARY 1948)

BY

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A PREDICTION OF WASHINGTON TEMPERATURE 1948 (MADE JANUARY 1948)

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Research Associate, Smithsonian Institution

ABSTRACT

The author in January 1948 predicted 55 dates in 1948 as near dates of minima in Washington temperatures. He predicted that between successive pairs of these dates higher temperatures would occur. He predicted that the average excess of these higher temperatures over those of the predicted dates would be 7°1 F. On January 19, 1949, the Director of the Astrophysical Observatory checked the prediction and found that in 48 of the 55 cases higher temperatures did intervene, and that their average excess was 6°96 F. The author shows by a graph that the main part of the brief fluctuations in temperature ordinarily ascribed to "weather" is caused by a periodicity of 6.6456 days in solar radiation, rather than by terrestrial complexities, as generally supposed. The author claims that similar successful predictions may be made for any station and, if desired, for many years in advance. The predicted dates of minima are approximate, and may be out of phase by 1, 2, or rarely 3 days. If predictions are limited to 1 or 2 months in advance, however, displacements of phase may be nearly eliminated. A prediction of approximate dates for Washington minimum temperatures for 1949 is given.

In January 1948 I made a prediction relating to temperatures at Washington for the entire year 1948. I then sealed the prediction and placed it in the safe in the Smithsonian accounting office, with the provision that it was to be opened on or about January 20, 1949, by the Director of the Smithsonian Astrophysical Observatory.

This paper contains the text of my prediction for 1948, the verification of the prediction by the Director of the Astrophysical Observatory, comments on the outcome, and my prediction for 1949.

PREDICTION FOR 1948

In Smithsonian Miscellaneous Collections, vol. 107, No. 4, 1947, I disclosed an average period of 6.6456 days in temperatures of Washington and other cities, identical in length with a periodic variation of solar radiation. Due, as I suppose, to complex terrestrial influences, the phases of this period shift somewhat as to tempera-

ture, though the phases do not shift in solar variation. However, it seemed to me probable that the period could be used for long-range predictions of temperature, though such predictions may sometimes be out of phase by from 1 to 3 days. I propose to make a prediction of Washington temperature for the year 1948 now [January 22, 1948], seal and deposit it with the Smithsonian Treasurer, to be opened and checked by the Director of the Smithsonian Astrophysical Observatory in January 1949.

The enclosed graph¹ contains plots of the departures from normal temperature at Washington for the years 1945-46-47. From a marked repetition of the 6.6456-day period of March 1946 I observed the phases of minimum temperature at that² time. Assuming no changes of phase, I indicated corresponding dates of minimum temperature for all repetitions of the period from January 1945 to December 1947. As these indicators in most cases bounded curves of higher temperature between each pair of indicators, I was encouraged to continue with my project.

Using the method described on page 4 of the paper above cited, and allowing for the fact that now I am concerned, not with "zero" dates but with dates of minima, I compute the following dates in the year 1948 as likely to be at or near dates of minima in the march of temperature at Washington:

1948	Jan.	5	11	18	24	31	July	2	9	15	22	29
	Feb.	7	13	20	27	..	Aug.	4	11	18	24	31
	Mar.	4	11	18	24	31	Sept.	7	13	20	26	..
	Apr.	7	13	20	27	..	Oct.	3	10	16	23	30
	May	3	10	17	23	30	Nov.	5	12	19	25	..
	June	5	12	19	25	..	Dec.	2	9	15	22	28

To verify the prediction I am about to make, the departures from normal temperatures at Washington, as published monthly by the United States Weather Bureau, should be taken for each of the dates tabulated above, and also the departure occurring at the highest temperature which occurred between each pair of dates. Then the mean value for the year 1948 of the departures for the dates above tabulated should be found to indicate a lower mean of departure temperatures than the mean departure of the said dates of "highest temperature."

I will also predict what the difference will be in degrees Fahren-

¹ Not here reproduced.

² See figure herewith.

heit between the two means of departures just indicated. For this prediction I take values from the three years 1945-46-47, selected as specified in the next preceding paragraph. The computed differences of these means are as follows:

1945, 6°6; 1946, 8°6; 1947, 6°0; Mean, 7°1

I predict the "Mean" just stated, for 1948.

Should the method of prediction succeed in Washington, it will probably succeed equally well in all other places. If any should be bold enough to use it, and wish to estimate how much difference in temperature between predicted maxima and minima is to be expected, he should consult figure 5 of the publication above cited and note that the range between maxima and minima varies several fold in Washington for the various months of the year.

VERIFICATION OF THE PREDICTION

January 19, 1949.

This is to certify that I have caused examination to be made of the sealed package deposited by Dr. C. G. Abbot in the Smithsonian safe in January 1948. I have tabulated the temperature departures from normal at Washington on the 55 dates specified therein, and the temperature departures at the warmest dates intervening between the 55 pairs, all as published in Weather Bureau Form 1030. I find that on 48 occasions warmer dates occurred between the dates specified, and that for the entire series of 55 dates the mean excess found thus was 6°96 F., as compared with 7°1 F. predicted by Dr. Abbot.

L. B. ALDRICH,

Director, Astrophysical Observatory.

COMMENTS

The test proposed in the preceding pages came out nearly as expected. But I realized soon after the manuscript was deposited, in January 1948, that the test might perhaps give an exaggerated impression of the amplitude of the 6.6456-day temperature fluctuation. For by using the highest temperatures which intervened between the predicted dates of minimum temperatures at Washington, there can be no question that some of these higher temperatures are made higher than they otherwise would be by local terrestrial meteorological influences, not directly caused by the solar periodic variation. Such extraneous influences may, it is true, have correspondingly

raised the temperatures at the predicted low dates. If so the error would be compensated. But one is inclined to think that this would not always be the case, and that the higher intervening values are higher in the mean than they should be in comparison with the values occurring on the predicted dates.

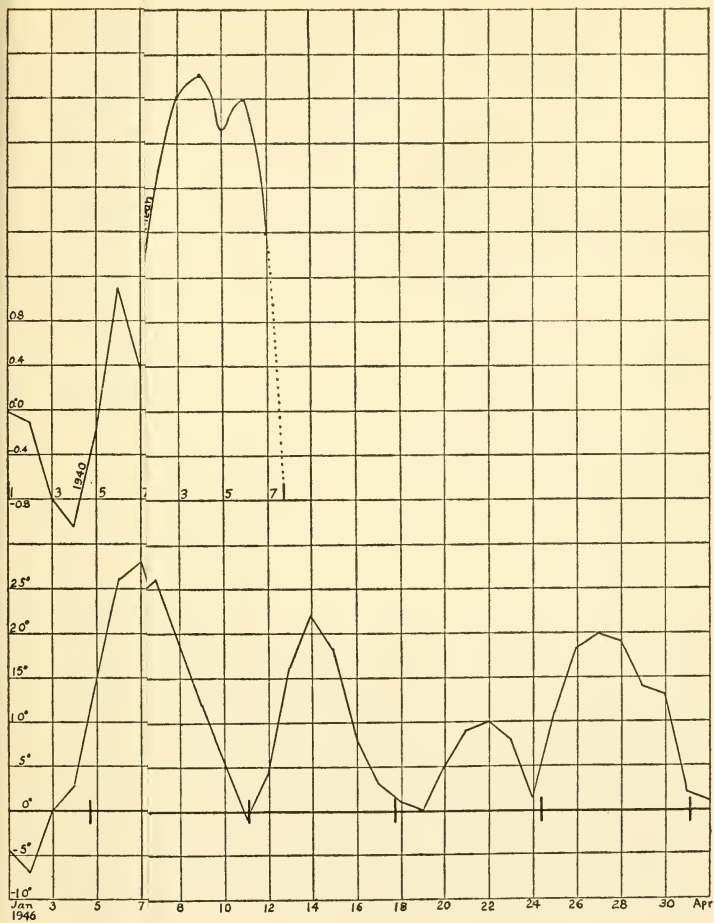
I sought a method to estimate the average increases of temperature between the predicted dates which would give too low a mean value of the excess. For this purpose I plotted the daily departures from the normal Washington temperatures from January 1 to April 1, 1946, as shown in the accompanying figure. Then with a scale divided into intervals of 6.6456 days, I marked, as shown by short, heavy vertical lines in the figure, the dates which seemed best to represent the minima of the 6.6456-day periodicity at Washington.⁸ Inspection indicated that January 17.0000 would be a proper date for the zero phase. From this date I calculated all corresponding phases from January 1, 1940, to December 31, 1948. Assuming these 495 dates to be exact dates of minimum temperatures at Washington, I computed yearly tables of temperature departures as arranged in groups averaging 6.6456 days in length. In these yearly tables of 55 lines each, approximately two out of every three lines were 7 days long, and the others 6. To arrange the short lines symmetrically I wrote 45 lines with the first space unfilled, and the rest with the seventh space unfilled.

Table I gives the mean yearly marches of the 6.6456-day periodicity

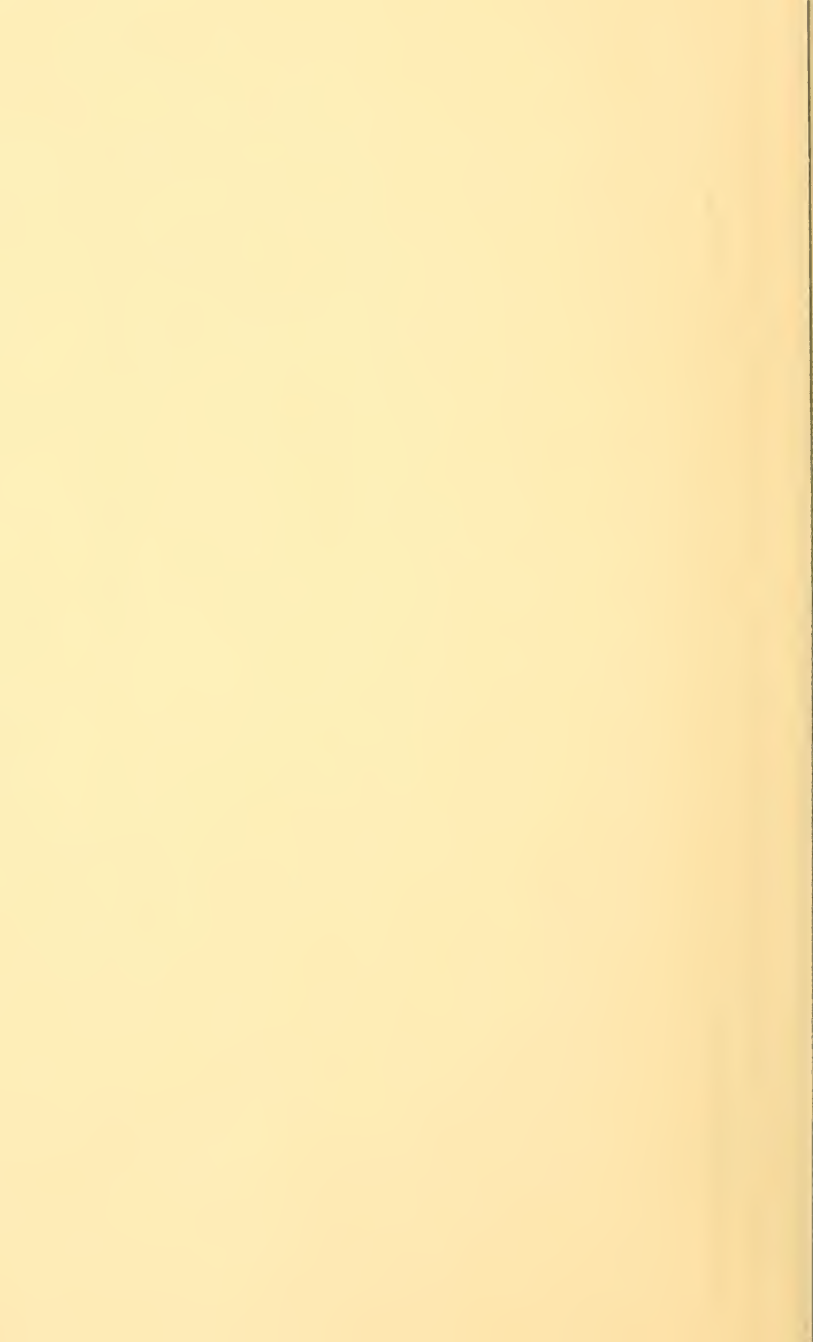
TABLE I.—*Mean march of 6.6456-day temperature groups at Washington in the years 1940-1948*

Year	Mean temperature marches							
1940	-0°02	-0°11	-0°80	-1°05	-0°20	+1°09	+0°34
1	2.63	2.31	1.76	3.65	3.31	3.18	1.72
2	0.22	2.16	2.98	2.96	3.49	2.27	2.29
3	1.84	2.62	2.78	2.80	1.38	1.00	0.76
4	0.61	1.49	2.69	2.38	2.85	2.11	1.02
5	1.86	1.84	2.09	2.13	2.51	2.49	2.24
6	0.72	2.16	4.62	4.31	3.36	2.78	2.64
7	-0.69	2.89	2.11	2.00	2.47	2.38	1.93
1948	1.49	2.25	1.93	1.45	1.33	3.44	3.02
Mean	1.08	2.20	2.62	2.71	2.46	2.59	1.99

⁸ It used to be the view of most meteorologists, and perhaps still is, that the brief fluctuations of temperature which we associate with the term "weather" are caused by terrestrial complexities. I think the figure shows plainly that they are mainly of solar origin.



indicated by short, thick, vertical lines.



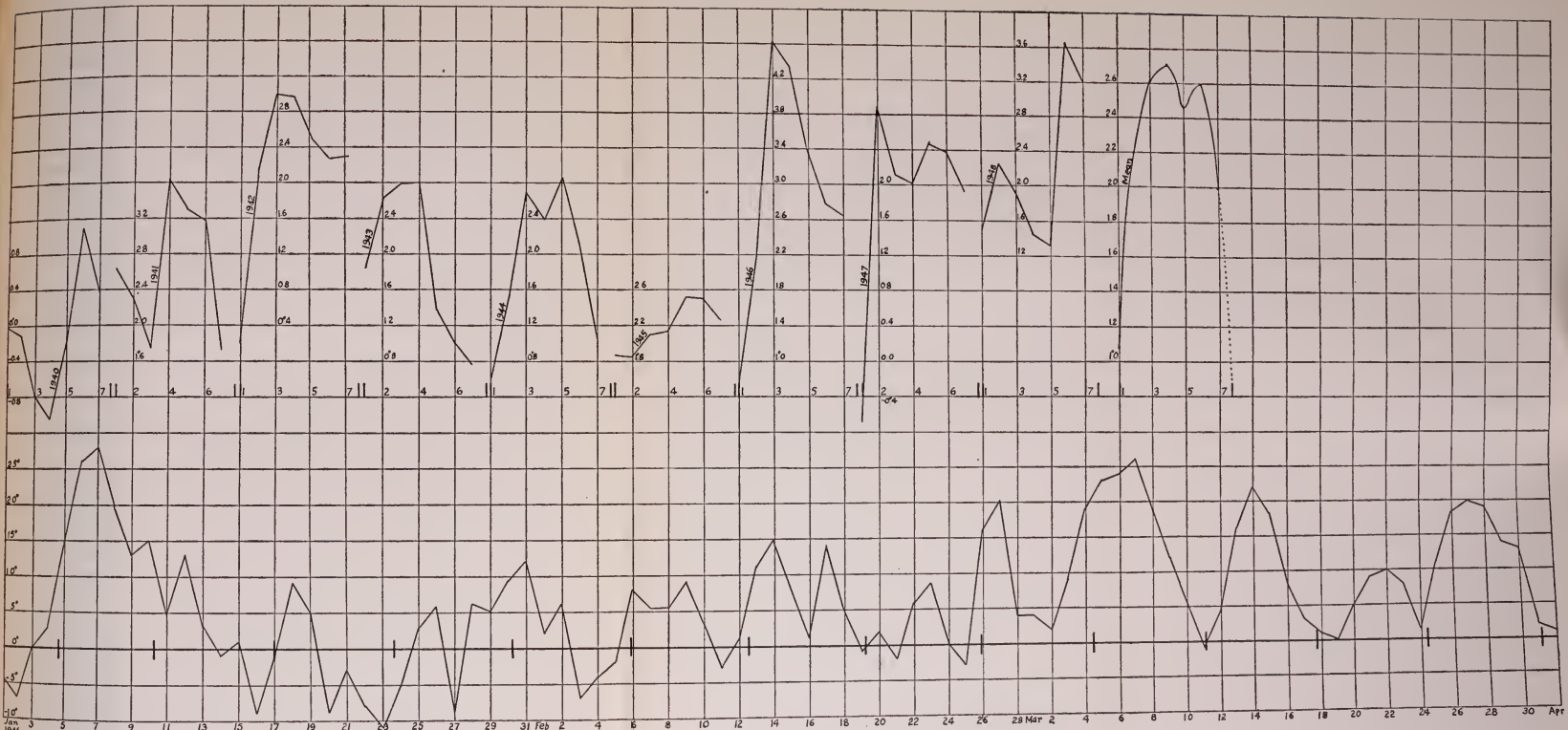


FIG. 1.—The 6.6456-day periodicity in Washington, D. C., temperature.

Lower curve, the daily departures from normal temperature, Jan. 1 to Apr. 1, 1946 (see Weather Bureau Form 1030). The 6.6456-day period is indicated by short, thick, vertical lines. Upper curves, average temperature departures for 55 repetitions of the periodicity each year, 1940-1948, and the mean of them for 9 years.



in Washington temperature departures for the 9 years 1940 to 1948. The upper part of the figure shows these results and their mean graphically. It is satisfactory to see that the mean curve is nearly smooth, with the correct phases for maximum and minima. The range of the mean curve is 1°63. This is certainly too low a value to be a correct estimate of the amplitude of the periodicity. For, as shown in my paper cited above, the phases of the periodicity are subject to a sort of backlash effect, and they are apt to occur 1, 2, or rarely 3 days too early or too late. Hence where, as in my tabulation just referred to, no allowance is made for these shifts of phase, the real mean amplitude of the periodicity must be much greater than computed.

I have computed also the average range per year after the method set forth in the test paper above. I give these results for the 9 years in table 2. They are very closely all the same, and give a mean of

TABLE 2.—Average amplitudes of the 6.6456-day temperature variations in Washington, 1940-1948

Years	1940	1941	1942	1943	1944	1945	1946	1947	1948	Mean
Amplitudes . . .	5°81	6°95	6°55	6°56	6°58	6°60	8°60	6°00	6°96	6°73

6°73. For the reason mentioned above, I consider this value too high an estimate of the amplitude of the 6.6456-day periodicity in Washington temperatures. But I do not think it as much too high as the other one, 1°63, is too low. However their mean, 4°18 F., may be nearly of the right order of magnitude.

While yearly forecasts of dates of minimum and maximum temperatures by this method may be out of phase by from 1 to 3 days, they may be made with equal success for many years in advance, as my earlier paper which covers 35 years shows. If the forecaster should content himself, however, with forecasts only a month or two in advance, and should take into account the phase prevailing when the forecast was made, he might hope to be within 1 day of correct phases for minima and maxima. See, for instance, in the lower part of the figure, how closely the phases held true from February 5 to March 31, 1946.⁴ The method, as I have said, is probably applicable everywhere.

⁴ Note also by the curves of the upper part of the figure that in the years 1940, 1941, 1945, and 1948 the phases were prevalingly appearing 2 days or more late.

PREDICTION OF APPROXIMATE DATES FOR MINIMUM
TEMPERATURES IN WASHINGTON, D. C., FOR THE
YEAR 1949

Following the method described in this paper, I give the following dates expected to be close to dates of minimum temperatures in Washington in the year 1949.

1949	Jan. ... 4	11	18	24	31	July ... 3	9	16	23	29
	Feb. ... 6	13	20	26	..	Aug. ... 5	12	18	25	31
	Mar. .. 5	12	18	25	..	Sept. .. 7	14	20	27	..
	Apr. ... 1	7	14	21	27	Oct. ... 4	10	17	24	30
	May ... 4	10	17	24	30	Nov. .. 6	13	19	26	..
	June .. 6	13	19	26	..	Dec. ... 3	9	16	22	29
						1950 Jan. ... 5	11	18	25	31

The departures of temperature from the normal, as published by the U. S. Weather Bureau, Form 1030, may be taken for these dates, and also for the warmest days that occur between them. Then the average excess of these warmer temperatures over the mean of the temperatures of two cool dates preceding and following each warm one will be found about 6°9 F. for the 55 cases of the year 1949.

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MONTEZUMA SOLAR-CONSTANT
VALUES AND THEIR PERIODIC SOLAR
VARIATIONS

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MONTEZUMA SOLAR-CONSTANT VALUES AND THEIR PERIODIC SOLAR VARIATIONS

By C. G. ABBOT

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We are convinced that solar-constant values from the Mount Montezuma, Chile, station are more accurate than those of any other Smithsonian station. This results from the meteorological superiority of the location. In three recent papers¹ (treating respectively of the 6.6456-day period in the solar radiation and in weather, of the trigger action of depressions of solar radiation to set off West Indian hurricanes, and of the effect of ionic bombardment of the earth to diminish solar radiation received here at times of great sunspot activity) I used the daily solar-constant values of Montezuma exclusively. The inclusion with them of less accurate data from our other stations would have been injurious in these studies of very small solar changes.

In volumes 5 and 6 of *Annals of the Smithsonian Astrophysical Observatory*, and in my paper "A Revised Analysis of Solar Constant Values"² the 10-day and monthly mean solar-constant values from several Smithsonian stations were combined in researches on long periods in solar variation. It seemed advisable to me to make a new search for long solar periodicities, using Montezuma data alone. I wished especially to test my former conclusion that all the periodic variations are integral submultiples of 273 months.

I have prepared a table of 10-day and monthly mean solar-constant values for Montezuma alone, from September 1923 to December 1947. They are given in table 1.

In table 1 the year and month are given in column 1. In column 2 appear the 10-day and monthly mean values of the solar constant, from Montezuma observations alone. Column 3 gives the number of days entering into these mean values. Readers should note that values in column 2 are to be understood as prefixed by the figures 1.9

¹ Smithsonian Misc. Coll., vol. 107, No. 4, 1947; vol. 110, Nos. 1 and 6, 1948.

² Smithsonian Misc. Coll., vol. 107, No. 10, 1947.

TABLE I.—Ten-day and monthly means, *Montezuma solar-constant values*
 Values given assumed to be prefixed by 1.9. Thus, 1.9536, etc.

1923		1924		1926		1927		1928	
9 I	536 9	12 I	506 5	3 I	439 7	6 I	479 8	9 I	— 0
II	531 8	II	470 1	II	515 4	II	427 6	II	442 4
III	540 8	III	518 5	III	393 8	III	433 9	III	410 4
M	536 25	M	508 11	M	435 19	M	447 23	M	426 8
10 I	446 9	1925		4 I	317 10	7 I	445 6	10 I	452 9
II	410 7	1 I	442 5	II	396 10	II	440 8	II	487 6
III	452 6	II	490 2	III	398 9	III	451 11	III	390 7
M	436 22	III	360 1	M	369 29	M	446 25	M	442 22
11 I	392 5	2 I	— 0	5 I	394 8	8 I	415 10	11 I	427 6
II	451 7	II	600 2	II	405 4	II	412 8	II	453 3
III	490 4	III	573 3	III	407 7	III	442 11	III	461 8
M	443 16	M	584 5	M	401 19	M	424 29	M	448 17
12 I	420 3	3 I	537 3	6 I	388 4	9 I	414 8	12 I	500 4
II	445 6	II	492 6	II	434 9	II	428 10	II	446 7
III	201 8	III	542 8	III	456 5	III	471 7	III	463 3
M	368 17	M	524 17	M	430 18	M	436 25	M	465 14
1924		1929		7 I	439 10	10 I	481 7	1 I	450 1
1 I	416 7	4 I	536 8	II	424 9	II	438 5	II	590 3
II	443 8	II	530 8	III	433 11	III	417 9	III	485 2
III	459 9	III	477 3	M	432 30	M	443 21	M	532 6
M	441 24	M	524 19	8 I	472 8	11 I	450 8	2 I	432 4
2 I	369 8	5 I	463 8	II	433 3	II	446 5	II	390 3
II	460 1	II	484 9	III	475 6	III	436 5	III	335 4
III	422 6	III	479 8	M	466 17	M	445 18	M	385 11
M	396 15	M	476 25	9 I	441 9	12 I	479 7	3 I	443 3
3 I	523 9	6 I	420 4	II	396 5	II	388 4	II	360 9
II	380 7	II	496 5	III	457 8	III	381 7	III	422 5
III	434 7	III	480 5	M	437 22	M	421 18	M	393 17
M	453 23	M	469 14	10 I	373 9	1928		4 I	370 10
4 I	392 5	7 I	510 2	II	423 10	1 I	442 6	II	492 9
II	416 7	II	510 6	III	374 8	II	374 5	III	442 10
III	432 9	III	436 8	M	392 27	III	476 5	M	435 29
M	417 21	M	473 16	11 I	359 8	2 I	480 6	5 I	420 6
5 I	467 9	8 I	477 9	II	357 6	II	433 7	II	430 5
II	493 7	II	442 6	III	405 2	III	470 1	III	436 10
III	506 10	III	431 8	M	364 16	M	456 14	M	430 21
M	489 26	M	452 23	12 I	333 3	3 I	464 7	6 I	395 6
6 I	554 7	9 I	524 8	II	359 8	II	464 5	II	344 5
II	492 5	II	470 10	III	370 1	III	468 6	III	413 7
III	522 6	III	471 8	M	353 12	M	466 18	M	388 18
M	526 18	M	487 26	1927		4 I	430 8	7 I	397 8
7 I	511 7	10 I	452 8	1 I	396 9	II	411 8	II	407 9
II	544 10	II	500 6	II	357 3	III	408 6	III	420 9
III	470 9	III	458 9	III	375 2	M	417 22	M	409 26
M	510 26	M	467 23	M	385 14	5 I	436 9	8 I	396 8
8 I	542 5	11 I	420 6	2 I	348 4	II	511 8	II	398 6
II	411 8	II	487 10	II	467 7	III	468 9	III	402 6
III	390 5	III	470 6	III	— 0	M	470 26	M	399 20
M	442 18	M	464 22	M	424 11	6 I	472 9	9 I	397 6
9 I	462 5	12 I	482 10	3 I	— 0	II	475 4	II	381 9
II	483 7	II	460 3	II	500 6	III	460 3	III	416 9
III	431 8	III	497 7	III	466 9	M	471 16	M	397 24
M	457 20	M	484 20	M	479 15	7 I	446 10	10 I	413 7
10 I	536 5	1926		4 I	446 5	II	435 6	II	442 4
II	524 8	1 I	473 7	II	472 9	III	413 6	III	370 3
III	528 11	II	499 7	III	414 8	M	434 22	M	412 14
M	528 24	III	390 5	M	445 22	8 I	444 5	11 I	419 9
11 I	557 9	2 I	405 2	5 I	426 8	II	449 7	II	422 5
II	494 8	II	410 5	II	426 5	III	440 6	III	480 8
III	498 6	III	400 1	III	420 11	M	444 18	M	442 22
M	520 23	M	408 8	M	423 24				

TABLE I.—Continued

1936		1937		1938		1939		1941	
3 I	304 9	6 I	472 8	9 I	462 6	12 I	375 6	3 I	575 4
II	340 8	II	451 7	II	448 8	II	473 7	II	545 4
III	412 9	III	443 3	III	479 10	III	445 9	III	540 9
M	352 26	M	460 18	M	464 24	M	435 22	M	549 17
4 I	417 4	7 I	— 0	10 I	470 8	1940		4 I	500 9
II	440 2	II	456 8	II	495 6	I	460 5	II	520 4
III	496 8	III	459 7	III	522 9	II	450 3	III	525 2
M	466 14	M	457 15	M	497 23	III	453 11	M	509 15
5 I	463 6	8 I	491 9	11 I	495 6	2 I	437 7	5 I	553 7
II	442 6	II	474 9	II	532 10	II	434 10	II	— 0
III	466 10	III	484 7	III	537 3	III	385 4	III	602 6
M	459 22	M	483 25	M	521 19	M	426 21	M	575 13
6 I	495 6	9 I	449 7	12 I	514 5	3 I	469 8	6 I	590 5
II	461 8	II	487 9	II	538 9	II	362 10	II	575 2
III	498 5	III	404 10	III	493 10	III	401 7	III	557 4
M	482 19	M	445 26	M	514 24	M	407 25	M	575 11
7 I	504 6	10 I	419 8	1939		4 I	435 2	7 I	637 3
II	441 7	II	434 10	I	— 0	II	458 9	II	560 9
III	455 11	III	540 5	II	— 0	III	544 7	III	554 5
M	463 24	M	452 23	III	400 2	M	489 18	M	572 17
8 I	420 4	11 I	503 9	2 I	424 7	5 I	519 9	8 I	566 7
II	470 6	II	457 6	II	— 0	II	486 8	II	542 4
III	455 8	III	505 6	III	463 6	III	510 9	III	480 6
M	442 18	M	490 21	M	442 13	M	506 26	M	529 17
9 I	385 4	12 I	518 5	3 I	420 3	6 I	486 10	9 I	540 8
II	430 10	II	570 3	II	442 5	II	491 7	II	509 7
III	486 9	III	541 8	III	452 8	III	516 7	III	585 2
M	444 23	M	540 16	M	443 16	M	496 24	M	532 17
10 I	426 5	1938		4 I	427 8	7 I	520 9	10 I	525 8
II	494 8	I	490 1	II	453 7	II	493 6	II	479 7
III	486 5	II	534 8	III	427 3	III	525 6	III	511 7
M	473 18	III	520 3	M	437 18	M	514 21	M	506 22
11 I	500 6	2 I	— 0	5 I	420 6	8 I	508 6	11 I	515 6
II	506 7	II	440 2	II	383 6	II	484 8	II	472 6
III	484 7	III	— 0	III	393 11	III	508 5	III	500 9
M	496 20	M	440 2	M	397 23	M	496 19	M	496 21
12 I	525 4	3 I	505 2	6 I	393 7	9 I	552 6	12 I	525 8
II	496 5	II	456 5	II	378 8	II	564 7	II	492 4
III	— 0	III	400 1	III	402 9	III	479 8	III	548 9
M	509 9	M	461 8	M	391 24	M	528 21	M	529 21
1937		4 I	445 8	7 I	420 8	10 I	450 2	1942	
I	— 0	II	432 6	II	388 9	II	472 4	I	565 8
II	450 1	III	462 6	III	398 6	III	486 7	II	536 5
III	477 4	M	446 20	M	402 23	M	476 13	III	494 5
M	472 5							M	537 18
2 I	513 9	5 I	458 9	8 I	373 8	11 I	408 6	2 I	496 7
II	470 4	II	430 5	II	354 5	II	447 9	II	499 7
III	516 5	III	396 7	III	417 8	III	414 7	III	460 6
M	504 18	M	430 21	M	385 21	M	426 22	M	486 20
3 I	389 8	6 I	420 6	9 I	476 7	12 I	429 7	3 I	413 3
II	403 6	II	454 5	II	447 6	II	492 5	II	409 10
III	407 8	III	460 4	III	452 8	III	507 4	III	444 5
M	400 22	M	442 15	M	459 21	M	468 16	M	419 18
4 I	372 9	7 I	441 8	10 I	447 6	1941		4 I	424 5
II	424 7	II	445 8	II	426 7	I	483 7	II	464 10
III	431 7	III	437 6	III	352 10	II	533 8	III	426 7
M	406 23	M	441 22	M	399 23	III	410 1	M	443 22
5 I	343 3	8 I	462 5	11 I	380 4	2 I	525 4	5 I	422 4
II	469 7	II	466 8	II	399 9	II	— 0	II	490 7
III	490 6	III	458 6	III	404 8	III	590 6	III	482 9
M	453 16	M	463 19	M	397 21	M	564 10	M	473 20

to give the complete solar constant in calories per square centimeter per minute.

Figure 1 shows graphically in curve A the march of the monthly mean values given in table 1. Curve B, on the same scale, gives departures from 1,945 calories remaining after 14 periodicities specified in table 2, below, have been removed from the original data given in column 2, table 1.

Table 2 also gives the yearly mean values, and numbers of days entering into them. It gives also smoothed-curve values derived from these yearly data, after plotting them as shown in figure 2. In the statistical search for periodic variations reported below, the smoothed-curve yearly mean values of table 2 were first to be removed by subtraction from the original monthly means. In order to do this the smoothed yearly means were first expanded graphically into a plot of smoothed monthly means. I do not take space to publish these smoothed monthly means, as their simple derivation will be easily understood, and as it makes no appreciable errors in the periodicities, to be given in table 2, whether these smoothed monthly means for eliminating yearly changes of the solar constant are the best that could be found or not; for these periodicities are found as means from statistical tables including many repetitions of the periods, and local errors are smoothed out.

In previous analysis of solar-constant values ³ numerous periodicities in solar variation were found to proceed simultaneously, all being approximately integral submultiples of 273 months in length. I did not wish to adopt this master period of 273 months in this present research without independently confirming it from Montezuma data alone. Figure 2, however, itself seems to indicate that a period of about this length would fit the yearly variations of the solar constant. There are researches of other authors which support the validity of a period approximating two 11-year sunspot cycles, as being in evidence in various solar and terrestrial phenomena. Thus G. E. Hale discovered that magnetism in sunspots reverses its polarity in a remarkable way with each successive sunspot cycle of 11 years, so that the sun's magnetic condition is restored only after two 11-year cycles pass, or about 22 $\frac{2}{3}$ years. A. E. Douglass has remarked a 23-year period in tree-ring widths. Various meteorologists have found it in terrestrial data. I myself pointed out that Wild's meteorological studies of the Russian Empire, when supplemented by later data, showed very clearly a 23-year cycle in weather at St. Petersburg.

³ Ann. Astrophys. Obs., vol. 6, p. 181, 1942; Smithsonian Misc. Coll., vol. 107, No. 10, 1947.

1960
58
56
54
52
50
48
46
44
42
40
38
1936
1948
46
44
42
40
38
1936



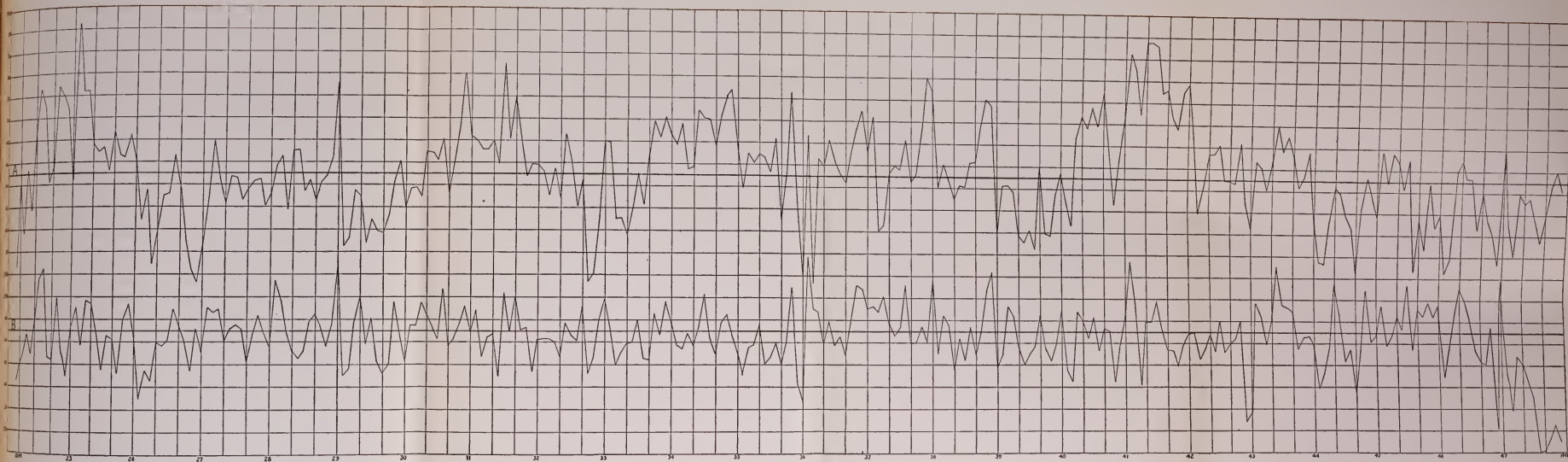


FIG. 1.—A, monthly mean march of solar constant, December 1923–December 1947, Montezuma station; B, residuals after periodic fluctuations removed.



Nevertheless, I began this present research without assuming a 273-month master period. First of all I removed the yearly variation from the values in column 2, table 1, as noted above. I then plotted the residual values and found that by far the most prominent periodic variation displayed in a large-scale plot of the residuals was of about 39 months. Seeking to fix its length as accurately as possible, by careful inspection of the large-scale plot, I finally decided on $39\frac{1}{2}$ months. I am not sure that the period may not be 39 months, which is exactly $1/7$ of 273 months; for the presence in the data of many other periodicities, and of accidental errors of observation, makes fixing of the exact length of a long period doubtful. Nevertheless, a table was prepared of seven columns, alternately of 39 and of 40 months in length. The mean of these columns is plotted in figure 3, *c*. As the reader will see, the march of this $39\frac{1}{2}$ -month periodicity is nearly a regular sine curve, and its amplitude is 0.0069 calorie, more than one-third of 1 percent of the solar constant.

The $39\frac{1}{2}$ -month periodicity was removed by subtraction to give a second list of monthly residuals. These also were plotted on a very large scale. There showed then a periodicity of considerable amplitude, approximately 91 months in length. A table 91 months long of three columns was made from the second residuals. With so few columns entering into the mean it seemed best to smooth the mean values by 5-month running means of them. The smoothed values being plotted, the 91-month periodicity appeared plainly, but superposed thereon there appeared a period of $\frac{1}{6}$ of 91 months. As it would be preferable to determine this curve of about 15 months by itself at a later stage, a smooth curve was drawn of 91-months period, cutting symmetrically through the 15-month superposed excrescences. The 91-month periodicity had the amplitude 0.0054 calorie. It is not of sine form, but rises rapidly to maximum, and falls slowly to minimum, like the well-known sunspot frequency curve of 11 years. This 91-month periodicity was removed from the data, leaving a third list of residuals, which were plotted on a large scale.

The third list, when plotted, showed clearly a strong periodic fluctuation of about 68 months. This was determined by forming a table of four columns, taking their mean, smoothing it by 5-month running means, and plotting the smoothed means in a curve given in figure 3, *b*. Very clearly there is a period of $1/7$ of 68 months superposed on the principal curve. Not wishing to evaluate a $9\frac{3}{4}$ -month periodicity until a later stage, I drew a smoothed curve as shown in figure 3, *b*. It is nearly of sine form, and has an amplitude of 0.0053 calorie, slightly under one-third of 1 percent of the solar constant.

It was now apparent from the behavior of the yearly variation of the solar constant, the excellence of the $39\frac{1}{2}$ -, 91-, and 68-month periodic curves, and the superposition of curves of $91/6$ and $68/7$ months, as noted above, that it is quite justified to regard 273 months as a master cycle in solar variation, and that many periodicities, nearly or exactly integral submultiples of 273 months, exist simultaneously therein. In all my subsequent search for periodicities in solar variation, as displayed in Montezuma solar-constant values, I accepted the 273-month master period, and sought for integral submultiples of it.

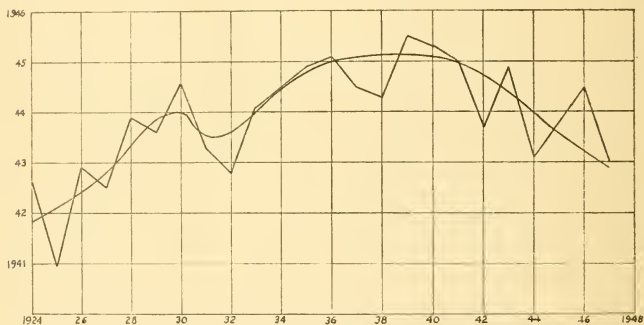


FIG. 2.—Yearly march of solar constant, 1924-1947.

Proceeding by the methods explained above, the periodicity of $54\frac{1}{2}$ months was next sought, found, and determined. Its amplitude is 0.0020 calorie, its form, like that of 91 months, comprises a rapid rise and slow fall. The curve, though smoothed by 5-month running means, has excrescences indicating the encroachment of a period approximating 8 months. Study of it was postponed, like those found with the 91- and 68-month periodicities, for later determination.

Attempts were then made to determine periodicities of $45\frac{1}{2}$, 34, and $30\frac{1}{3}$ months. But these proved so far dominated and obscured by variations of shorter periods that they were all passed over for the time. However the curve drawn when seeking a periodicity of $30\frac{1}{3}$ months clearly indicated a periodicity of half that length, of fairly large amplitude. So the next search made concerned $15\frac{1}{6}$ months. It will be noted that solar variations of 273, 91, 68, and $54\frac{1}{2}$ months period had now been extracted from the monthly data, and that the fourth list of residuals was now being used.

A period of $15\frac{1}{2}$ months is $1/18$ of 273 months. It was now practicable to divide the data into three groups, and tabulate them in 6-line tables of 15 columns.⁴ In this way it could be decided if the supposed $15\frac{1}{2}$ -month period continued in all three sections of the interval of 273 months. Figure 3, *a*, gives the mean curves for the three tabulations and the general mean. The three group means

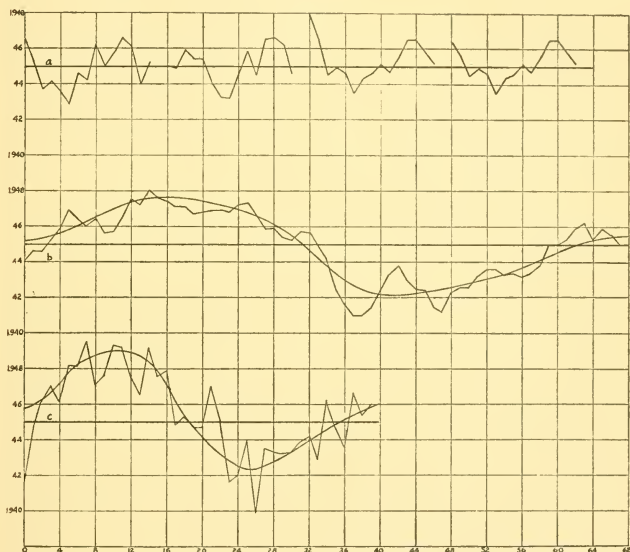


FIG. 3.—Examples of solar periodic fluctuations. *a*, $15\frac{1}{2}$ months. Observations 1924-31; 1932-39; 1940-47; and 1924-47; *b*, 68 months. 1924-47; *c*, $39\frac{1}{2}$ months. 1924-47.

show no certain secular displacement of maxima and minima, have nearly similar forms, and nearly equal amplitudes. Hence their mean was taken as shown in figure 3, *a*, and is regarded as a very well-determined periodicity of solar variation with an amplitude of 0.0030 calorie. This mean curve, being well supported in detail by the group means, is used unsmoothed, and the departures of it from

⁴ Whenever a periodicity not of exact months is determined, values or columns are omitted occasionally in tabulations, so that the mean values of columns fit the exact length of the periodicity.

1.945 calories were subtracted from the fourth list, giving a fifth list of residuals.

Though convinced of the validity of the assumption of a 273-month master cycle, I have passed over any discussion of the sunspot cycle of $11\frac{1}{2}$ years, approximating one-half of the master period. I now take up its consideration before noting the discovery of several other periodicities. Figure 2, which displays the variation of the yearly means of Montezuma solar-constant values, does, indeed, show depressions at the years 1925, 1931-32, 1937-38, and 1944. These may indicate a sunspot-cycle influence, but might better be attributed to the 68-month cycle which has already been discussed. Moreover, these depressions appearing in figure 2 are very small, with amplitudes only about $1/12$ of 1 percent of the solar constant, yet the 68-month curve, when specifically determined as given above, has an amplitude approaching $\frac{1}{3}$ of 1 percent.

Meteorologists recognize that the 11-year sunspot cycle is reflected in temperature, precipitation, and barometric pressure. Aldrich, also, has shown⁵ by the study of individual daily values of the sunspot numbers, and of solar-constant values, that there is a complex correlation between these phenomena. But my residual plots of monthly solar-constant values do not show any 136-month periodicity of appreciable amplitude. This is not really in contradiction to the findings of meteorologists. It is well known that the sunspot areas bombard the earth with electric ions. These, by acting as centers of condensation for water vapor and dust in the earth's atmosphere, may very well be competent to produce meteorological changes. Besides this, the ozone contents of the atmosphere may be affected by them in a way to influence meteorological phenomena. So we may recognize two kinds of solar influences on meteorology. One depends on variations of the solar radiation, the other on variations of ionic bombardment.

Having discovered and evaluated periodicities of 273, 91, 68, $54\frac{1}{2}$, $39\frac{1}{2}$, and $15\frac{1}{6}$ months in the variation of solar radiation, as evidenced by monthly mean solar-constant values of Montezuma, I next used the original 10-day mean values to seek for periodicities of less than 12 months. For such short periods the longer ones hitherto discussed produce no sensible interference. It would be tedious to recite all these trials. The method was always the same. By means of a long paper scale divided at regular intervals to represent a suspected period, I tested on the long plot of 10-day means whether such a

⁵ Smithsonian Misc. Coll., vol. 104, No. 12, 1945.

period seemed to be likely. If it seemed so, I arranged the 10-day mean values in groups of tables, each comprising about one-fourth of the total interval 1924-1947. They were never less than six lines long, and with as many columns as there were 10-day intervals in the proposed period. Where periods were not exact multiples of 10 days, values were omitted, or columns were omitted, occasionally, to bring the average lengths of the lines to that of the proposed period. The criterion of a true period was always that the several group tables agreed substantially in their means, as to phases and amplitudes of the suggested period, throughout the whole 273 months. Such good agreement is shown for the $15\frac{1}{6}$ -month period in figure 3, *a*. In several cases proposed periods failed to meet this test, and were rejected. Sometimes the phases shifted regularly from group to group through the 273-month interval. In such cases the period was shortened or lengthened to give unchanging phases.

As a result of this branch of the investigation, periodicities of $5\frac{2}{15}$, 8.035, $9\frac{3}{4}$, $11\frac{1}{3}$, $11\frac{15}{16}$ months were recognized as true, according to the above criterion. Being incommensurable in length, there was no need to subtract them one by one from the data. They could not materially influence each other. After determining them in the 10-day mean data, they were transformed into monthly means. Then their marches were tabulated throughout the 273 months, their amplitudes added algebraically at each month, and the algebraic total per month was subtracted from the fifth residual list, remaining after removing the longer periodicities named above. This left a sixth list of monthly residuals for further exploration.

To shorten a tedious story, the methods explained above, when applied to the sixth list of residuals, discovered additional periodicities of $14\frac{1}{3}$, $19\frac{1}{2}$, and $24\frac{1}{2}$ months. When all had been removed from the data, no other periodicities seemed worth investigation in the residual plot remaining. It is plotted as curve B of figure 1.⁶ The mean of the departures from 1.945 calories in curve B is 0.00189 calorie, or 0.097 percent of the solar constant. Many of the larger departures, which materially raise the mean as just given, occur in

⁶ One disturbing feature will be noted in figure 1, B. Though the year 1947 shows no remarkable eccentricity in curve A, it gives a great slump of $\frac{1}{2}$ percent in curve B. This is strange, for all the periodicities seem to fit the last year's data, including 1946, as well as the earlier years, as we see from figure 1, B. One notes, however, that curve A of figure 1 is almost entirely below 1.945 calories in 1947. It may be that the Montezuma values of 1947 are subject to a yet undiscovered error. Further observations of future years will decide.

the months December to February, when the atmospheric conditions at Montezuma are less favorable, and when many days are lost to observation. It cannot be claimed that the periodicities removed are perfectly correct in forms. Hence the final residuals are larger than they should be on this account also. We may conclude that of the variations of solar radiation indicated in figure 1,A, and which exceed 1 percent in range, accidental error of observation contributes less than 2/10 percent, and the periodic variations nearly 1 percent of the total range.

In table 2 I gave the details of the 14 periodicities in the variation of solar radiation, which have been discovered. There may be others of less than 5-months period, some of minor amplitude, and still others exceeding 273 months in period, which our observations have not yet continued long enough to discover. Indeed the large fluctuations of Great Lakes levels occurring at intervals of about 45 and 91 years seem to indicate that the double and quadruple of the master period of 273 months are of very great importance in meteorology. There is also the noted Bruckner period, of about three sunspot cycles, which may also be found eventually in solar-constant values if they continue to be observed for some years longer.



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SOME STAGES IN THE EVOLUTION OF
THE NERVOUS SYSTEM AND THE
FORE-GUT OF THE POLYCHAET

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INTRODUCTION

As polychaets are primitive among the annelids, so are the Errantia among the polychaets; and the Eunicimorpha among the Errantia. Though the Amphinomorpha, since the work of Storch (1913), have by many been placed at the base, the Eunicimorpha are in many respects the most primitive. This is seen in the brain with its extended form and marked subdivisions, and in the stomodeum with its fold form and the very small amount of its protrusibility. This paper, at its first inception in 1926 (!), was suggested by the characters of *Eunice* (*Leodice*) as given by Heider (1925, see p. 61).

The Amphinomorpha also are primitive; especially (as is generally supposed) in their tetra-neury, in their brain (except for the hind-brain), in the absence of specialization in the buccal segments, and in the small protrusibility of the pharynx. But they seem less primitive than Eunicimorpha: in their brain, both by its greater concentration and the enormous development of the "hind" or nuchal brain; and in their stomodeum, both by its cylindrical form and greater protrusibility.

The great antiquity of the Eunicimorpha is indicated by the annelid jaws (scolecodonts) which have long been known. They are abundant in Paleozoic rocks; and great numbers of species have recently been described, especially by E. R. Eller, from various horizons between the Middle Ordovician and the Upper Devonian. Practically all those described up to the present belong to the Eunicimorpha (e.g., Eller, 1945). Sometimes the denticles of both the "upper" and "lower" jaw series are found in their natural association (Lange, 1947). The claims made in this paper, however, give them a very much greater antiquity than the Ordovician.

Indications of evolution are best seen in these most primitive forms; but all the errant forms furnish evidence in varying degrees. The specialized "sedentary" families are naturally less satisfactory for this study and need not be considered, but their ancestors doubtless experienced the same evolution.

For the presentation of the theories given below, it is not necessary to discuss the origin of segmentation. The evolution pictured followed the acquirement of segmentation, and points back to a ringed worm more primitive than any now existing. Moreover, it preceded the acquirement of the trochophore larval stage.

The brain with its complement of sense organs and appendages, the stomodeum, and the visceral nervous system are all markedly compound in errant polychaets; and it is the chief purpose of this paper to claim that their structures are connected in origin.

THE BRAIN OF EUNICE

The brain by its form, especially in *Eunice*, suggests an origin in a complex and lengthy aggregation. Hatschek, 1891, and Racovitza, 1894, were the first to divide the brain into fore-brain, mid-brain, and hind-brain. Heider (1925, figs. 7, 12, 13, 15, 16) does the same; and he determined minutely the external features of the neuropil mass (see figs. 1, 3, 4, and 5, p. 6).

These three "brains" are here claimed to constitute three distinct categories of nervous matter.

The *fore-brain*. This separates itself from the rest by its position, form, structure, the senses it serves, and the gap above and behind it (through which pass muscles of the mouth-lips, the so-called "palps" of many authors). It is suggested here that this was the *primary* brain, and as an archicerebrum may well have had a complicated history of its own. It receives the ventral root of the perioesophageal commissure; and gives origin to the two pairs of stomatogastric nerves and to nerves of the mouth-lips.

The *mid-brain*. This, the main brain, innervates the prostomial appendages and the eyes. It is clearly subdivided into *three* successive sections diminishing rearwards—an anterior, middle, and posterior. The *anterior* receives the dorsal branch of the perioesophageal commissure, and innervates the anterolateral antennae; the *middle* innervates the single pair of eyes and the posterolateral antennae; the *posterior* innervates the median antenna and the posterior eyes when present. Heider, like Pruvot, instituted only two divisions: the last two here instituted forming his posterior division; but in his figures (loc. cit., figs. 12 and 13; see also figs. 3, 4, and 5 accompanying this paper) they are very clearly distinguishable from one another.

The antennae are comparable with the tentacular cirri of the second buccal segment and with the cirri of the normal body segments. The eyes too may well be homologous with the pigment spots on the body segments above the parapodia and gills. Each of these three subdivisions of the mid-brain is below claimed to originate in a separate pair of body ganglia added to the brain at *different* times, and to be the only parts which have homologues in the ventral chain.

The *hind-brain* is much smaller, having only a small fraction of the volume of even the smallest (the posterior) division of the mid-brain. It consists of two separate ganglia: these innervate the nuchal organs, which have no counterpart elsewhere in *Eunice*.

These three "brains," the fore, mid, and hind, thus constitute three distinct categories, distinct not only in character, but also, it is believed, in their origins and their histories as explained below.

HISTORY OF OPINION REGARDING THE CONSTITUTION OF THE BRAIN IN POLYCHAETS

As the theory here submitted differs so fundamentally from all previously presented, a short sketch of the diverse opinions regarding the origin and significance of the brain was written, but is withheld in order to shorten this paper. The views of the various authors beginning with Pruvot in 1885 (see list of references, p. 33) are extremely varied; they are summarized in table 1. The theory of

TABLE I.—Summary of opinions regarding the significance of the brain*

Brain divisions first suggested by Hatschek	Fore-brain or stomatogastric lobes	Mid-brain or antennal brain			Hind-brain or nuchal brain
		Anterolateral antennae	Posterolateral antennae	Median antenna	
Pruvot, 1885	Seg. 1 with mouth lips and palps	Seg. 2		Seg. 3	
Hatschek, 1891		Seg. 1			
Racovitza, 1896		Nonsegmental brain			Seg. 3
Holmgren, 1916					
Nilsson, 1911-1912	Seg. 1	Seg. 2			Seg. 3
Lameere, 1925					
Binard and Jeener, 1928		Seg. 3	Seg. 2	Seg. 1	
Hanström, 1927, 1928	Seg. 1, added in some only	Nonsegmental brain			
Söderström, 1920		Nonsegmental brain			Outside the brain
Gustafson, 1930	? Seg. 1 after	The nonsegmental brain			Added to the brain
Raw, present paper	Ancient brain A	BIII	BII	BI	C
		GAP	Gap	Gap	

* Since this paper was finished and submitted for publication, papers by Laura M. Henry (1947, 1948) have appeared, discussing the segmentation of the anterior region of the body in Oligochaeta, Polychaeta, Onychophora and Arthropoda. Her outlook is quite different from that presented here. Her principle, derived from Hanström and G. F. Ferris, is the stability of the nervous system in the Annelata. She takes the oligochaet brain as the most primitive; though, having lost all eyes and antennae, it must be degenerate. She regards *Nereis* as presenting the simplest nervous system—a basic type from which the other forms can be derived. According to her the polychaet brain is a unit: the visceral nervous system belongs to it, and it innervates her "segment I", which is represented by *the jaws only*; her "segment II" (the first apparent segment of the extended proboscis) is innervated by the connective ganglion. The prostomium "belongs either to the third or fourth body segment." In one respect she agrees with views expressed here, viz, that the proboscis represents segments; but in most other respects her conclusions are widely different.

the present writer, expressed cryptically on the last line, is developed below.

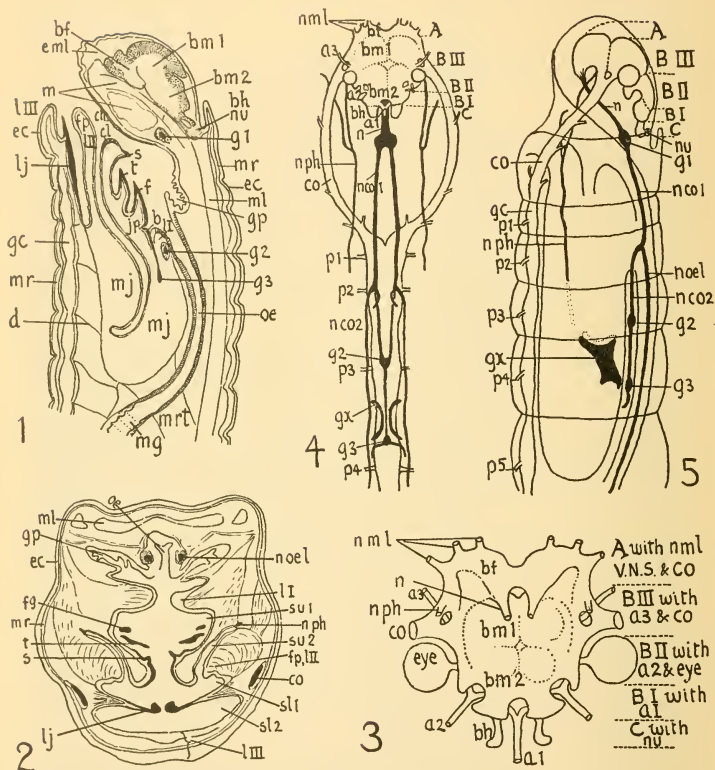
SIGNIFICANCE OF THE DIVISIONS OF THE BRAIN IN PRIMITIVE POLYCHAETS

The *fore-brain*. Both the morphological position and the importance assigned to the fore-brain vary greatly. By Pruvot and by Nilsson it was regarded as the *first* of three head segments (though the other two of these supposed segments given by the one are different from those given by the other). Hanström, on the other hand, is in the opposite camp, regarding it as the sole *addition* to the brain. To Hatschek, Racovitza, Binard and Jeener, and Söderström it was perhaps of little significance.

But in primitive polychaets, as already remarked, it is separated from the mid-brain by an extensive muscle gap and may exhibit large size as in *Eunice* and *Euphrosyne*. In polychaets generally it gives issue to a pair of stomatogastric nerves, and in primitive forms it innervates the mouth-lips which evidently preceded antennal palps in the palpal function. This strongly suggests its great antiquity as an element of the brain. If, however, the stomatogastric lobes of the Amphinomidae and Euphrosynidae were the exact equivalent of the fore-brain of *Eunice*, as Gustafson seems to claim, there is a significant difference between them; for the ventral root of the perioesophageal connective enters the fore-brain in *Eunice*, but does not enter the stomatogastric lobes in these other families. This great discordance does not seem to have been remarked by Gustafson, and needs explanation. The equivalent in Amphinomidae of the fore-brain must also include the part which receives the ventral root of the perioesophageal connectives.

The characters and relationships of the fore-brain, therefore, quite justify one in assigning it to a different category from that of the adjoining mid-brain; and the fact that in the most primitive polychaets it innervates the organs which function as palps, suggests that it is the primal brain.

The *hind-brain*. The significance of the hind-brain is clarified by the discoveries of Söderström. It again falls in quite a different category from that of the mid-brain, as is indicated by its innervation of the nuchal organs alone. The fact, too, that in the Amphinomidae and Euphrosynidae these organs extend over several segments of the body, and that the hind-brain in them is so developed as to suggest the incorporation in it of several pairs of nuchal ganglia, suggests that the hind-brain is the *latest* addition to the brain. This is also



FIGS. 1 to 5.—All the figures are traced from Heider's; and the present author's interpretation is added on the right side of figures 3, 4, and 5.

FIG. 1.—(After Heider's fig. 7.) Diagrammatic longitudinal vertical section through the anterior part of *Eunice punctata*. The oesophagus and the median plane ganglia are shown in median section; but the brain and the jaw sacs are represented as cut at one side of the median. $\times 12$.

FIG. 2.—(After Heider's fig. 10.) Oblique cross section from the third segment behind the peristome on the dorsum forward to the lower lip. $\times 20$.

FIG. 3.—(After Heider's fig. 13.) Brain of *Eunice punctata*, ventral aspect. Ca. $\times 20$.

FIG. 4.—(After Heider's fig. 15.) Dorsal view of the brain and the anterior parts of the central nervous system and visceral nervous system of *Eunice punctata*. Ca. $\times 10$.

FIG. 5.—(After Heider's fig. 16.) Side view of the same. Ca. $\times 15$.

ABBREVIATIONS USED ON FIGURES 1-5

The central nervous system is in outline, the visceral nervous system is in black in figs. 4 and 5.

*a*₁, nerve of the posterior single antenna. | *a*₂, nerve of the posterior pair of antennae. | *a*₃, nerve of the anterior part of antennae.

b, bearer. | *bf*, fore-brain. | *bm*₁, anterior section of mid-brain. | *bm*₂, Heider's hind section of mid-brain. | *bh*, hind-brain.

ch, chitin thickening on the base of the prostomium. | *cl*, callus on the jaw-pad. | *co*, buccal commissure.

d, dissepiment. | *ec*, ectoderm. | *eml*, epithelium of the mouth-lips.

f, fang. *fp*, fore pad = *l II*.

*g*₁, supra-oesophageal ganglion of visceral nervous system. | *g*₂, infra-oesophageal ganglion of visceral nervous system. | *g*₃, hindmost oesophageal ganglion. | *gc*, ventral ganglion chain. | *gx*, x-form ganglion body. | *gp*, glandular pouch.

jp, upper jaw pad. | *l I*, lips of pharyngo-oesophageal rift. | *l II*, lips bounding the upper jaw sacs. | *l III*, lip bounding the lower jaw sacs, the lower lip. | *lj*, lower jaw.

m, muscles of the prostomium. | *mg*, beginning of mid gut. | *mj*, muscles of the jaw sac. | *ml*, dorsal longitudinal muscle. | *mr*, ring muscle layer. | *mrt*, retractor of the jaw sac.

n, oesophageal visceral nerve or nerves (from the fore brain). | *n co 1*, oesophageal visceral commissure, anterior part. | *n co 2*, ditto, posterior part; in figure 4 it is the inner pair joining in *g*₂; the outer pair is *n oe l*, following. | *n oe l*, lateral oesophageal nerve. | *n ph*, pharyngeal visceral nerve | *nu*, nuchal organ.

oe, oesophagus. | *p*₁ to *p*₅, podial nerve roots.

s, saw-plate. | *sl1*, *sl2*, sacs of the lower jaw. | *su1*, *su2*, sacs of the "upper" jaw. | *t*, "tooth."

The present author's views as to the evolution of the brain and of the gut are suggested by the order of the capital letters A, B, C (respectively fore-, mid-, and hind-brain), and the Roman figures I, II, and III for the three successive invaginations and the three different ganglion pairs in the mid-brain. The original brain was the fore-brain and the corresponding gut the mid-gut. The first addition to the gut was the oesophagus—I, after which B I was added to the brain. The second addition was the upper jaw series of sacs with their armature—II, after which B II was added to the brain. The third addition was the lower jaw sacs with their armature—III, after which B III was added to the brain; which then incorporated also the hind-brain—C. The sequence of lower lips resulting from the successive invaginations are still represented by *l I*, *l II*, and *l III*, the present lower lip. The concomitant evolution of the visceral nervous system need not be repeated here.

suggested by the fact that "both Kleinenberg (1886) and Meyer (1901) have shown that the ganglia of the hind-brain are marked off from the ganglia of the nuchal organ and incorporated in the brain" (Gustafson, 1930, p. 339). The same writer supposes that it will be the same in other polychaets.

The *mid-brain*. The most primitive form of mid-brain seems to be exhibited by *Eunice*, where its extension in a plane and its strong suggestion of segmentation into three successive and well-defined divisions, which can be called mid-brain III, II, and I, can be regarded in that light. Hanström (1927, p. 592; 1928, pp. 259, 260), it is true, is very dogmatic in his expression of the opposite view; but the facts are against him. The anterior and largest pair, mid-brain III, innervate the anterolateral antennae ("palps" of authors), and receive the dorsal branch of the periesophageal connectives. The middle pair, mid-brain II, innervate the posterolateral antennae and the eyes. The posterior and much the smallest pair, mid-brain I, innervate the median antenna, which, contrary to the view of Binard and Jeener, is best regarded as a coalescence of two; when two pairs of eyes are present, as in some eunicids, the posterior smaller pair may with confidence be assigned to this brain division.

In the other primitive brains, those of *Euphrosyne* and of Amphinomidae the mid-brain is still extended in a plane, and its parts have the same topographical relations to one another, but the subdivision into three pairs is not immediately apparent. The identity, however, of the succession of nerves with similar topographical relations strongly suggests a composition of the same three divisions III, II, and I.

The antennae compare so closely in *Eunice* with the pair of tentacular cirri on the second body segment and with the dorsal cirri on the other body segments, as is the case also in the Amphinomidae and in many other families, that it is quite natural to homologize them. The eyes again associated with mid-brain II and I can be regarded with great probability as serially homologous with the pigment spots on the body segments of *Eunice*.

From the comparisons below instituted with the visceral nervous system, the writer believes that the three divisions of the mid-brain represent three segmental body ganglia which have been added to the fore-brain at *three* different times—I, the posterior, first; III, the anterior, last—and that they do not belong to adjoining segments of the ancestor.

The supposed origin of these parts by the secondary subdivision of a unit brain—Hanström's "fore-brain," consisting of our mid-

and hind-brain—into four divisions, grouped above in two categories (Hanström, 1928, pp. 259, 260), and the grading of the three divisions of our mid-brain by posteriorly diminishing size is very difficult to imagine; whereas on the theory detailed below it follows quite naturally.

THE STOMODEUM IN EUNICE AND OTHER POLYCHAETS

At the outset in this paper the Eunicimorpha have been claimed as primitive, but it may be thought by some that in respect of their stomodeum they are less primitive than some others. Hempelmann (1934, in Kükenthal and Krumbach, Handb. Zool., vol. 2, 7, p. 161, Annelida Polychaeta systematic section) divides the Polychaeta Errantia into—(1) suborder Amphinomorpha with tetraneury; and (2) suborder Nereimorpha with dineury, of which the first family described is the Aphroditidae and the last the Eunicidae. From this one might think that he regarded the Aphroditidae as the most primitive and the Eunicidae as the most specialized. When, however, we note that the systematic part is a translation of Fauvel in Fauvel's order, except for the extraction of the Amphinomidae and its elevation into a suborder, we may conclude perhaps that the order was without significance for Hempelmann.

The stomodeum of the Eunicimorpha is unique among errant polychaets—in its form, its armature, and its very slight protrusibility. Its form is remarkable, consisting of the pharynx subdivided into four successive sacs separated by foldings of the pharynx wall, followed by the cylindrical "oesophagus." All the sacs, and the oesophagus as well, extensively communicate with one another by rifts in the midline. The armature, too, is remarkable and of great variety within the suborder; but by comparisons between the various types the courses of evolution can be clearly seen. The denticles are arranged within and on the ventral sides of two of the sacs in all forms, constituting respectively an upper jaw series of pairs of denticles and a lower jaw with a single (chisel and crusher) pair. The evolution of the armature could form a separate paper. In *Eunice* only the lower jaw chisels and the upper jaw fangs are protruded. The primitive symmetrical pairing of the denticles, well seen in *Stauronereis* (*Staurocephalus*), has been lost in the Eunicidae, s.s.

In the Amphinomorpha the stomodeum, though very different, presents the nearest approach to that of the Eunicimorpha in the very small amount of its protrusion and in the fact that this is largely limited to the ventral side, recalling the condition in *Eunice* where

only the ventral lower jaw and fangs are protruded. In the Nereimorpha (as restricted by the exclusion of these) the pharynx is cylindrical and is often far protrusible, reaching its greatest length and protrusibility in the Glyceridae and the Goniadidae, which because of their unique conical, secondarily annulated prostomium, might well constitute a suborder, the Glycerimorpha. This long, cylindrical, far protrusible proboscis the writer regards as a high specialization.

THE STOMATOGASTRIC NERVOUS SYSTEM IN POLYCHAETS

A visceral nervous system has been known since the time of Stannius (1831), who investigated that of *Amphinome rostrata* and showed that the stomatogastric nerves issued both from the brain and from the first ganglia on the perioesophageal connectives. Pruvot (1885) showed that such a system occurs generally in the polychaets, the nerves issuing in different cases either only from the brain as in *Eunice*, or both from the brain and from the oesophageal connective as in *Nephtys* and *Phyllodoce*, or only from the perioesophageal ring as in *Ophelia*. A double origin has also been shown by Rodhe (1887) for the Aphroditidae (Polynoe), viz, from the brain and from the first perioesophageal ganglion. In *Nereis* according to Hamaker (1898) and Holmgren (1916) the innervation is from the brain and from the suboesophageal ganglion. The visceral nervous system of *Eunice*, described in considerable detail by Heider, and that of *Hermione* described by Bernert, are fairly closely comparable with one another. In all cases there are two pairs of stomatogastric nerves, one pair of which arises in the fore-brain near the midline. It therefore is probable that all are inherited from the primitive polychaet.

So far as the writer is aware the origin of the visceral nervous system has not been determined or even deduced. Heider remarked upon its individuality in opposition to the remaining part of the nervous system; and he concluded that it had a separate origin.

INTERRELATIONS OF THE STOMODEUM, THE VISCERAL NERVOUS SYSTEM, AND THE BRAIN IN THE ANCESTRY OF EUNICE

The purpose of this paper is to show how closely related, in the writer's view, are the stomodeum, the visceral nervous system, and the brain; and how strongly a parallel evolution of all three is suggested by the anatomy of *Eunice*.

The compound stomodeal system (of oesophagus and pharynx)

and the visceral nervous system are closely associated with one another. Throughout their common extension the visceral nerves and ganglia are in the stomodeal hypodermis. And it is suggested that these two systems are also connected in origin; indeed, that the visceral nervous system is a direct result of the stomodeal invagination; that before the invagination commenced, the present visceral nervous system would not exist, and the brain would consist only of fore-brain!

The *stomodeum* is very complex and the invagination that gave rise to it must have been very complex, probably much more so than we can realize (see Heider, 1925, figs. 5 to 10; also figs. 1 and 2 in this paper, p. 6). Though so complex, it divides itself quite naturally into three divisions: (1) the oesophagus; (2) the sacs associated with the upper jaw armature; and (3) the sacs associated with the lower jaw armature. Three successive invaginations or series of invaginations appear therefore to be represented, which must have been separated by long halts, and probably imply changes of feeding. The first is represented by the oesophagus; and this would seem to have very long antedated the other two, represented by the upper jaw series and the lower jaw series of pharyngeal sacs, which were separated by a shorter interval. At each of these later invaginations, the new was not merely an extension of the old, but a new structure lying ventrad of the old (fig. 1).

The first or oesophageal invagination was probably a protracted process; it is represented by the long oesophagus, commencing in front of the mid-gut and bounded by the lips of the pharyngo-oesophageal rift (*l I*, figs. 1 and 2), which, but without the rift, may represent the lower lip at the end of that stage.

The second or upper jaw series was also probably a long process: its effects were to produce the main cavity of the pharyngeal sac with the upper jaw sac above it, and bounded below by the "fore-pad," which again, but without its rift, may represent the lower lip of that stage. It contains the so-called "upper jaw" apparatus, the different elements of which—the bearers, fangs, saw-plates, and "rub plates"—are here interpreted as representing several pairs of appendages! In the more primitive eunicid, *Cirrobranchia parthenopcia*, seven such pairs of appendages might seem to be indicated; but comparisons throughout the suborder show that it is impossible to judge of the number involved, and this is not surprising when it is realized that the evolution of the stomodeum took place very long before Cambrian time and probably over 1,000 million years ago.

The third or lower jaw invagination adds a further pair of pockets

to the pharyngeal sacs. It contains the "lower jaw" plates, here interpreted as representing another pair of appendages added to the mouth armature; and it is bounded by a new, the present, lower lip (*l III*).

Each of these pharyngeal invaginations has produced a two-fold sac, each sac being partly subdivided by the pair of pads, which can be likened to parapodia, on which the pair or pairs of denticles are situated. Besides the rifts between these pads, the parting between the upper jaw sacs and the lower jaw sacs, as also that between the upper jaw sac and the oesophagus, are markedly bifid. This suggests that with the evolution of each new sac the previous lower lip became bifid owing to the necessity for through-communication through the sacs to the oesophagus.

The *visceral nervous system* and its distribution, as suggested above, are explicable as direct results of the invaginations, which not only involved ordinary ectoderm and pairs of appendages, but also the "central" nervous system, which was still continuous with the ectoderm. It may not be possible to assign to each invagination its exact contribution to the visceral nervous system; on the other hand this is clearly subdivisible into an oesophageal and a pharyngeal section.

At this early stage, too, the main nerve cords from the brain were in a more primitive position than now obtains; for, judging from the parts of the visceral system both on the oesophagus and the jaw sac, they were ventrolateral, not midventral, in position; and, that this was still the case after the evolution of the polychaet, is suggested by the far-separated ganglion chains of *Serpulae* and of some arthropods.

Seeing that each invagination was rearward in direction, its effect on the nerve chains, when it involved them, was to *pull them back into a pair of loops open in front*; and their anterior connections, i.e., with the brain, were enormously stretched, in contrast with their posterior connection, i.e., with the continuing nerve cords. An effect of this is to be seen in the fact that the oesophageal visceral nerve cords from the fore-brain are quite free from the hypodermis, until, in the supra-oesophageal visceral ganglion, they reach the oesophagus. The stretch has pulled them free, as it has also the fore-brain.

The open loop in the nerve cords, *after each invagination* that involved them, seems to have been closed by the *advance of the foremost of the unaffected ganglia to the brain*. Such a change might be aided by the existence of a hypodermal nerve net.

It is not to be expected that the whole history will now be trace-

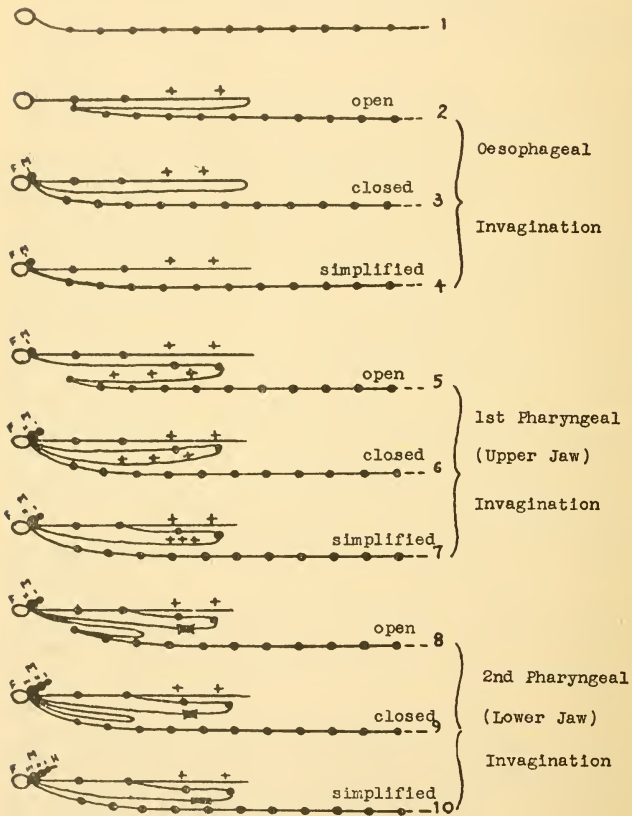
able, for nature in such an unimaginable time would simplify a system complicated by repeated invaginations. And in any case a more detailed knowledge of the visceral nervous system is needed than is furnished by Heider, if we are to trace the history as completely as is still possible. The development of these interrelations is illustrated by table 2, stages 1 to 10, pp. 14-15.

The effect of the most ancient, the *oesophageal invagination*, on the disposition of the nervous system is to be seen in the oesophageal nervous system; but it is perhaps difficult to interpret. Heider described a considerable system, all of which, excepting the connection with the brain, lies in the oesophageal hypodermis (Heider, 1925, pp. 77 and 78). From the posterior lappets of the fore-brain the visceral oesophageal nerves (*n*, fig. 3), freed from the hypodermis, and soon apposed to one another, extend to the supra-oesophageal visceral ganglion (figs. 4 and 5, g_1); thence the separated pair of nerves continue rearward (figs. 4 and 5; *n co 1*), and both then branch, one branch of each (*n oe l*, figs. 4 and 5) continuing presumably for the length of the oesophagus in the side pads (fig. 2), the other (*n co 2*, figs. 4 and 5) continuing rearward to join its fellow in the infra-oesophageal visceral ganglion (g_2 , figs. 1, 4, and 5). According to Heider the visceral oesophageal ring, thus completed, has the character of a long-stretched ganglion. From the infra-oesophageal visceral ganglion a single cord in the ventral wall of the oesophagus extends rearward to a terminal ganglion g_3 (at the level of the 4th podial nerves). From this a pair of nerves go to the sides of the upper jaw sac, and so join up with the pharyngeal system.

The oesophageal visceral nerve ring mimics the oesophageal central nerve ring; but the union of the visceral nerves in the midventral line of the oesophagus calls for explanation, in view of the evidence for the lateral position of the nerve cords at that early period. Might it be due to mechanical drag imposed by the upper jaw sac invagination?

The oesophageal visceral nervous system is much more complex than our ideal oesophageal loop; but some redistribution may well have taken place, since the time when the oesophagus was the whole of the fore-gut. If appendages were present, and were invaginated, as is probable, they have disappeared, having been superseded by those of the jaw sacs. The narrowness of the visceral oesophageal ring in contrast with the great width of the corresponding ring of the central nervous system can be attributed to the total absence of oesophageal appendages in contrast with the size and the action of those of the pharynx.

TABLE 2 (with stages 1 to 10).—*Supposed stages in the evolution of the central and visceral nervous systems of the polychaet*



Stages 1 to 10 of table 2

Stages.

1. Brain and left ventrolateral nerve cord of the annelid ancestor of the polychaet. (The nerve cord was possibly not ganglionated at this stage. The podial-longitudinal and the nuchal nerves are omitted.)
2. The *oesophageal invagination* has produced open nerve loops, along which lie an unknown number of ganglia.
3. These oesophageal nerve loops have been closed by the advance of their terminal ganglia to the brain to form mid-brain I.
4. The oesophageal nerve loops have been simplified as suggested by the present visceral oesophageal nerves.
5. The *1st pharyngeal or upper jaw invagination* has produced open nerve loops, along which lie a considerable number of ganglia.
6. These upper jaw nerve loops have been closed by the advance of their terminal ganglia to the brain to form mid-brain II, which has pushed I to the rear.
7. The upper jaw nerve loops have been shortened by a coalescence with the visceral oesophageal cord.
8. The *2nd pharyngeal or lower jaw invagination* has produced an open nerve loop without, however, involving any ganglia.
9. These loops have been closed by the advance of their terminal ganglia to the brain to form mid-brain III, which has pushed II and I to the rear. (In this way I has been pushed up to the 1st nuchal ganglia which will join it as hind-brain.)
10. These nerve loops have aborted and the hind-brain is added.

The contrast between the oesophagus and the upper jaw sac could hardly be greater; and one can conclude that the interval between these invaginations was an enormous period of time. In this interval the open loops in the nerve chains would be closed; and the fore-brain would receive its most ancient addition. Judging from the structure of the brain this is now the posterior section of the mid-brain (mid-brain I); its small size (quite out of proportion with II and III) suggests its great antiquity. It would carry with it, too, a pair of cirri and a pair of eyes. At this time it would lie immediately behind the fore-brain (table 2, stages 3 and 4). The process just envisaged would have two advantages for the animal: first, the visceral nerves, as they had become, would thus constitute a system of their own, apart from the "central" nerve cords, according with their contrasting functions; and, second, the segmental ganglia behind the new effective mouth acquired again direct connection with the brain, thus rehabilitating the "central" or rather the ventrolateral nerve cords, as they then were.

The *first pharyngeal invagination*, comprising the compound upper jaw sac subdivided by the jaw pads, appears to be mainly responsible for the pharyngeal part of the visceral nervous system. The second pharyngeal invagination, the lower jaw sac, appears to have added only the anterior part of the pharyngeal nerves, as explained below, p. 18. The upper jaw sac, together with its bounding bifid lips above and below (II and III, fig. 2) is highly muscular; and, except for the muscles extending from it, it is bounded laterally by the body cavity. One of its great functions is its eversibility, allowing the fangs to be shot out to seize prey. This is largely effected by extroversion of the main long sac beneath the jaw pad.

Heider was unable to trace the nervous system throughout; but he believed his detached parts to be continuous, as suggested in his figure 16 (see also fig. 5, accompanying this paper). Except for the connections with the brain, all lie in the hypodermis of the jaw sac, and are lateral in position, from which we can infer that the nerve cords were still lateral and in the hypodermis. The nerves connecting with the oesophageal section have already been mentioned. Supposed to be connected with these are the pair of main nervous centers in the pharynx—Heider's "X-form bodies" (figs. 4 and 5; *gr*). In plan these are irregularly quadrangular, with concave sides and horn-like angles, and they lie over the muscular posterior bases of the jaw pads, on either side of the dividing rift and with their convexities directed toward one another. Each consists of a nerve-fiber mass covered with a layer of small ganglion cells.

Heider, after satisfying himself as to the nervous character of the bodies, suggests that they are motor centers for the muscles of the jaw pads; and though he could not trace connections, he suggests that their posterior horns may connect with the nerves from the terminal visceral oesophageal ganglion g_3 , and that their anterior ventral horns connect with the two visceral pharyngeal cords.

We can agree with Heider that the function of this pair of nerve centers is connected with the muscles of the jaw pads; but we can go further and suggest, on the theory here advanced, that each X-form nerve center is due to coalescence of the ganglia (lateral at that time) of the segments, the appendages of which are represented by the upper jaw apparatus, and the highly modified muscles of which are represented by the muscles of the jaw sacs. There is close coordination of the appendages, and there is union of the ganglia serving them.

The two pharyngeal cords of the visceral nervous system arise from the sides of the fore-brain via the anterior roots of the oesophageal commissures, and extend rearward to the side wall of the pharynx. They are traced by Heider as far back as opposite the second ventral ganglion and podial nerves. Their course is along the deepest (farthest sideways) part of the main sac, ventrad of the lateral bases of the jaw pads, and closely clinging to the hypodermis.

If Heider's supposed connections are correct we have here a nerve course from the fore-brain rearward to the main visceral nerve center in the pharynx, forming one side only of a visceral loop, the other side of which is to be found only in the oesophageal section. If at one time the ancestor of *Eunice* had separate oesophageal and pharyngeal nerve loops, their adjoining halves forming an opposite loop have disappeared. But if connection between the outside halves was effected, the connection of the inside halves with the brain would be redundant. Such a connection might be caused by the sharp folding of the hypodermis which the stomodeum exhibits, or might arise when the lip between the two invaginations became bifid.

On the general theory applied above to the oesophageal invagination, the evolution of the upper jaw sac was followed by the advance of the foremost unaffected segmental pair of ganglia to join the brain, thus completing the previously open pharyngeal loop. This is represented by the *middle pair* of the three mid-brain "ganglia," numbered II (the second in size and the second in antiquity) of the additions to the brain. It appears to have *arrived* like its predecessor *behind the fore-brain*, and to have *pushed the previous addition to the rear*; for the anterior section of the "mid-brain," considered below, was

the last to arrive, as indicated by the fact that it bears the visceral pharyngeal nerves and the roots of the oesophageal commissures, and further, they all *three* diminish in size from front to rear. Each of the three parts of the mid-brain carried with it to the head a pair of cirri, and the first two also a pair of eyes; for each segment in *Eunice* generally bears a pigment spot with the structure of an eye just above each appendage. The cirri survive as the antennae of the prostomium, but usually in *Eunice* one pair only of the eyes survives, belonging to mid-brain II. These eyes must have superseded earlier eyes innervated by the fore-brain. When a second pair of eyes exists, these are a posterior pair and belong to mid-brain I. The union of the pair of cirri belonging to this last into the median antenna may be connected, first, with the relegation of the brain division serving it to so posterior a position and, second, with its small size as compared with mid-brain II and III (see table 2, stages 5 to 7).

The *second pharyngeal* or *lower jaw invagination* comprises the two sacs beneath the "fore-pads." The upper of these sacs is bounded on its ventral side by the lower jaw pair of plates, there implanted. The median edges of these are free and thickened, forming a pair of crushers, between which the two sacs are in communication; whereas the anterior edges are sharp and form a pair of chisels. Not improbably the infolds bearing these plates may represent the highly modified parapodia of a single segment, opposed to one another by the invagination.

No ganglia or considerable nerves are associated with them, attributable to this invagination; and hence its ganglion pair is probably the one which, with its pair of cirri, subsequently advanced to the brain. Perhaps by this time the nerve cords were more ready to free themselves from the hypodermis. Probably the nerve cords were still lateral in position, or at least not closely approximated in the ventral line as now. On our theory the ganglia of the lower jaw segment were the last of the ganglia from the central nerve cords to join the brain, forming mid-brain III, the largest as well as the last of these additions. Like their predecessors, they in their turn addressed themselves to, and arrived behind, the fore-brain, for they alone of the mid-brain divisions receive the oesophageal connectives; and they, too, pushed their predecessors to the rear. Again, they brought to the fore-brain not only the central nerve cords which in this case persist as the oesophageal connectives with their *two* roots, but also the ends of a new loop of the visceral nervous system which persist as the pharyngeal nerves, reaching the brain with the ventral roots of the oesophageal connectives. As before, the other end of this loop has been short-circuited and has disappeared.

Mid-brain III, the anterior section, does not carry an eye in polychaets. Perhaps it is because by this time the eyes of the head were so much more efficient than the segmental eyes of the trunk that the pair belonging to the lower jaw segment has aborted. On the other hand, it should be noted that the present first body segment is without an eye-spot, so the abortion may have been effected earlier.

It will be agreed that the presence of five (the equivalent of six) similar antennae, as is still seen in the Eunicidae and the Amphinomidae, is the primitive condition in the polychaet. The development of so great a number by nature on *part* of a unit brain, such as is conceived either by Racovitza or by Hanström, is extremely improbable, if not indeed unimaginable; whereas, on the theory here advanced, it follows quite naturally.

The parallel evolution of the mid-brain, the stomodeum, and the visceral nervous system have now, it is hoped, been read at least in outline.

COMPLETION OF THE BRAIN

The mid-brain has now been evolved and added to the fore-brain. Arguments have already been advanced for the addition of the hind-brain or nuchal brain last of all. Its incorporation is probably to be attributed to the rearward extension of the brain due to the successive additions of mid-brains I, II and III, which brought mid-brain I to aggregated ganglia of the nuchal organs. This suggests that the incorporation of the hind-brain and of mid-brain III took place at the same time. This completed the basic plan of the polychaet brain. Söderström, however, who first claimed that it was an addition from the body, claimed also that for this reason it could not form part of the prostomium. But had he espoused the theory here advanced, on the same principle the whole of the mid-brain would have to go. Gustafson, though he accepted the first claim of Söderström, retained the nuchal brain as part of the brain and presumably of the prostomium. On the theory here presented there is still greater reason to accept the hind-brain as an integral part of the brain and of the prostomium. This question is further discussed below (p. 25).

SUMMARY OF THE AUTHOR'S THEORY

Now that the intimate relationships between these three systems of the brain, the stomodeum, and the visceral nervous system have been deduced and outlined, it is advisable to picture in greater detail the *modus operandi* of these supposed changes which are illustrated by table 2, stages I to 10.

As discussed below, we can hypothecate for the primitive annelid the presence of three pairs of longitudinal nerve cords represented now by the nuchal nerves, the podial longitudinal nerves, and the ventral nerve cords. Their positions in the primitive annelid, if symmetrical, would be dorsolateral, lateral, and ventrolateral respectively. As the annelid was already segmented, we can call these nerve cords the nuchal, podial, and ventral *chains*.

In the primitive annelid (table 2, stage 1) the *primal brain*, represented by the present fore-brain, must already have constituted the dominant nerve center of the body; and, judging from the structure of the brain of the polychaet and especially the eunicid, it must have *retained its dominance till the brain was completed*. The *original* anterior ends of the ventrolateral nerve cords or "ventral chains" issuing from the primal brain are represented *now* by the *visceral oesophageal cords*, not by the perioesophageal connectives. The invaginations may all have been brought about by the animal finding it useful to employ appendages within its alimentary tract and therefore invaginating them. Further, as its habits changed and the appendages improved, this was effected three times over. This mode of origin seems especially probable in the two pharyngeal invaginations where we still have the armature in each case; and if it is accepted for them, it can with great probability be hypothecated also for the oesophageal invagination where all armature is absent.¹ The effects of the stomodeal invaginations upon the primal ventral chains may ultimately be read in detail; but if the podial chains were also involved, we cannot at present cite effects due to them.

The *oesophageal invagination* (table 2, stages 2 to 4). The oesophageal nerve loops produced by this (fig. 2) are perhaps represented now only by the oesophageal cords extending from the brain to the supra-oesophageal ganglion (g_1) of the visceral nervous system, the upper half of the ganglionlike circumoesophageal ring (*n co I*) and the continuations rearward in the main lateral pads of the oesophagus (*n oe l*, figs. 4 and 5, Heider, 1925, pp. 86-88). Unknown primal "ganglia" along the last are suggested by a few plus signs. The loops were closed by the advance of the foremost pair of uninvaginated ganglia to the brain (fore-brain) to form *mid-brain I*, bringing with them the ventral sides of the oesophageal loops and the ventral chains (table 2, stage 3). The nerves were brought up to, and appropriated by, the fore-brain, whereas the mid-brain I presided over a pair of

¹ But the idea was first suggested to the author by the characters of certain trilobites, where several pairs of appendages seem to be entirely hidden within the alimentary tract.

antennae and a pair of eyes. For after the invagination the parapodia of this segment may well have become restricted to a pair of dorsal cirri—"tentacular cirri"—as in the first body segment of *Eunice*, associated with a pair of eyes, present on all the other body segments; and both cirri and eyes advanced to the prostomium with their ganglia. The oesophageal loops, though represented in stage 4 as simplified, may perhaps have continued in existence until the simplification of the first pharyngeal, stage 7.

The *1st pharyngeal invagination* (stages 5 to 7). The pair of nerve loops due to this (stage 5) are apparently represented by the lower half of the oesophageal ring and the cords joining g_2 , g_3 , and the X-form body, together with part of the pharyngeal cords (*n ph* of figs. 4 and 5). The unknown primal ganglia along it are again suggested by a few plus signs.

The loop was closed (stage 6) by the advance of the foremost uninvaginated ganglia to the brain to form mid-brain II, which also carried with it pharyngeal cords of the visceral nervous system and the ventral chains. But, as after the oesophageal invagination, it was to the fore-brain that they came, entering between this and mid-brain I and pushing the latter to the rear. As yet, there was no fusion between those brain parts. Again the fore-brain appropriated these added nerves, which arrived outside of the previous system. Mid-brain II again, like I, had to preside over the pair of antennae (the previous "tentacular cirri") and the pair of eyes, which had advanced with these ganglia.

After this stage came a simplification of this 1st pharyngeal visceral nerve loop, and not improbably of both the oesophageal and 1st pharyngeal loops together (stage 7). If two complete loops still existed, much was redundant, and the dorsal side of the first pharyngeal seems to have joined the dorsal side of the oesophageal; whereas other parts aborted.

The 2nd pharyngeal invagination. This, the lower jaw invagination (stage 8), may be expected to have produced small nerve loops. No ganglia are associated with the lower jaw, so no ventral ganglion pair was involved. The invagination was probably due to the use by the mouth of the previously foremost pair of extra-stomodaeal appendages, the dorsal cirri of which at the same time functioned as tentacular cirri! These appendages are represented by the lower jaw plates and pads.

The new visceral nerve loop was closed by the advance of the foremost pair of ventral-chain ganglia to the brain, in the same way as before, to form mid-brain III (stage 9). With them to the prosto-

mium traveled the tentacular cirri of the time to form the antero-lateral tentacles. No eyes accompanied this third pair of cirri; and it has been mentioned that eye-spots have been lost from the first body segment (that with tentacular cirri) in *Eunice punctata*.

The added ganglia, following the established rule, addressed themselves to the fore-brain, as had their predecessors, whom they in turn forced to the rear. They trailed again the ventral cords and by applying themselves to the fore-brain caused the double roots of the oesophageal connectives. They brought also with them new visceral nerves—the present fore-brain roots of the pharyngeal visceral cords. It is significant that these arise from the ventral roots of the oesophageal connectives—both were brought together, and at the time of the addition of mid-brain III.

How exactly the simplification of this visceral system was effected may not be clear; but the three courses of stage 9 imply redundancy, and one course alone seems to have survived, namely, the most ventral, because this alone would be associated in origin with the new oesophageal connectives.

One other change and the basic plan of the brain was completed: mid-brain I had now been pushed so far to the rear that it has approached the nuchal ganglia and these also have added themselves in stage 10 to constitute the hind-brain. With this the brain of the ancestral polychaet has been evolved. The stomodeum is completed, and this has involved the completion of the brain.

LIMITS AND SIGNIFICANCE OF THE PROSTOMIUM OF THE POLYCHAET

Regarding the extent of the prostomium, there has been much difference of opinion: it has indeed been a subject of keen controversy. But there is perhaps no need to recall here the numerous divergent views. Considering the great antiquity of the polychaets, it is not surprising that the head should present great variety, and suggest different opinions. The ideal prostomium, the prototype, is the *region in front of the mouth in the common ancestor of the group*; and this may be expected to be indicated by what the most primitive polychaets have in common there. By previous writers this seems generally to have been equated with the prostomium of the hypothetical primitive annelid; but this is opposed by the claims advanced in this paper.

As to its nature and origin, two markedly contrasted conceptions have been held: (1) that in its origin it was segmental in some way or other; (2) that it was a unit, and unsegmented (see table I,

p. 4). Söderström, who held the latter view, sought in effect to change its definition into *the unsegmented anterior region of the body*; and he cast scorn on all who had not the same "prostomium idea." Such a definition is, however, quite unjustifiable.

The conclusion of Binard and Jeener, supported also by Gustafson and accepted by the present writer, is that the primitive appendages of the head comprise an anterior pair of antennae, modified in some forms into palps; a second pair, never so modified; and a median antenna. These are innervated by successive parts of the mid-brain. The morphological order of these appendages was naturally of less importance to those who regarded the prostomium as a unit, than to those who thought of it as segmented. The earlier writers, previous to Lameere, all placed them in their order of position—the anterior pair first, the median antenna last. Lameere reversed the order, and was supported by Binard and Jeener. Hanström seems to have accepted the reversal, but did not accept Lameere's theory. Gustafson was apparently in doubt, and perhaps for that reason numbered them chaotically. The present theory erected in entire ignorance of that of Lameere, also reverses the order, but for an entirely different reason; moreover, whereas according to Lameere the sequence of the three "pairs" was already developed in the *coelenterate* ancestor, on the present theory the three pairs of ganglia that innervated them (as well as the antennae themselves) were picked at random, so to speak, by nature out of a long sequence of postcephalic segments during the evolution of the polychaet, and carried forward to the head. Besides five antennae, the prostomium bears also two pairs of eyes. Even those who have recognized segmentation in the prostomium have not regarded the eyes as segmental; but the author claims that they belong with the intermediate antennae and the median antenna, and are thus segmental in origin (pp. 16, 18, 21, and 22).

Previous to the researches of Söderström on the Spionidae the prostomium was always considered to include also the whole of the compact mass of nervous matter constituting the brain. He, however, homologizing the nuchal organs with the dorsal, segmental, chemical sense organs of the Spionidae, which extend through the whole body, claimed that the hind-brain and nuchal organs must therefore be excluded from the prostomium. On the other hand, all the most primitive polychaets have a hind-brain closely associated with the remainder, and possess also these nuchal organs; hence there is every reason to credit the ancestral polychaet with a hind-brain and nuchal organs, and therefore to include these parts in the prostomium. And just as the nuchal organs have their homologues on the

postcephalic segments of the Spionidae, so the antennae have theirs in the dorsal cirri of the body segments, and the eyes have theirs in the postcephalic eye-spots. The principle on which Söderström would exclude the hind-brain is invalid, and is reducible to an absurdity. On the theory here advanced it would also exclude the whole of the mid-brain, the antennae, and the eyes. Furthermore, reason has above been given for the incorporation of the hind-brain at the same time as mid-brain III. Again, on the theory advanced by Hanström it would exclude the fore-brain and the mouth-lips! The principle is wrong: Söderström did not allow for any evolution within the annelid. We must get back to the primitive idea, and define the prostomium as *all that region in front of the mouth inherited in that position from the primitive polychaet*. On the theory here advanced this includes: (1) the fore-brain and the representative of the "mouth-lips," inherited from the head of the more primitive annelid, together with the following parts acquired in order by the prostomium during the evolution of the head of the polychaet: (2) the hind section of the mid-brain (mid-brain I) with the median antenna (due to coalescence of a pair), and a pair of eyes (the posterior pair); and long afterward (3) the middle section of the mid-brain (mid-brain II) with the second pair of antennae, and the anterior pair of eyes; and again long afterward (4) the anterior section of the mid-brain (mid-brain III) with another pair, the anterior, of antennae; and also (5) the hind-brain with the nuchal organs; these two brain parts (mid-brain III and the hind-brain) being probably acquired nearer the same time.

Gustafson, who is doubtful whether to accept the theory of Hanström that the stomatogastric lobes (or fore-brain) have been added from the ventral chain, is doubtful therefore whether to regard the mouth-lips, which they innervate, as part of the prostomium. Nothing better illustrates the enormous contrast between the present theory and that. What Hanström regards as the last addition is here claimed as the original nucleus.

Many may be surprised at the inclusion here of the hind-brain after Söderström's important and significant work; but it will be clear that the same principle, which would exclude it, would exclude also the whole of the mid-brain and all the cephalic tentacles and eyes.

It will thus be seen that the theory here advanced presents a new conception of the prostomium. It is not the representative in modern forms of the head of the primitive annelid, but the result of the long evolution from this of the head of the polychaet. It is not a unit as so many have supposed, but an aggregate, acquired only in the

course of unimaginable time. It is not due merely to the cephalization of additional anterior segments of the body as many have supposed, but is largely due to the advance to the brain of three pairs of segmental body ganglia at three far separated times, and, at the same times also, advance to the head of three segmental pairs of cirri and two segmental pairs of eyes, to become the cephalic sense organs. Incidentally this aggregation caused the brain to incorporate also the hind-brain innervating the nuchal organs, which are therefore just as much parts of the prostomium as are the other cephalic sense organs and the mid-brain.

Further, this great *aggregation of the brain* and the cephalic sense organs, which built up the polychaet prostomium, is claimed here as *incidental to the evolution of the stomodeum*, which again is referred to changes in the mode of feeding.

MORPHOLOGICAL SIGNIFICANCE OF THE HIND-BRAIN

The nuchal organs are quite dorsal in position. This is seen very clearly in the Spionidae which in some forms retain them completely; and it is indicated also by their position in the errant polychaets. But in these it is only in the tetraneural Amphinomidae and Euphrosynidae that extensive development of the nuchal organs occurs. Here development of the caruncle is accompanied both by great enlargement of the hind-brain (presumably by the addition of their ganglia), and by tetraneury; and again the nuchal organs are quite dorsad of these nerves. These relationships suggest that the ancestor of the polychaet, before the evolution of its brain, stomodeum, and visceral nervous system was characterized by *sexneury* having: (1) a pair of ventral nerve cords (still persisting as the ventral nerve cords of the central nervous system), (2) a pair of lateral or podial nerve cords (still retained only in the tetraneural families above mentioned), and (3) a pair of dorsal or nuchal nerve cords (still retained by the Spionidae, greatly developed and cephalized by the tetraneural families, and greatly reduced subsequently in other families).

The mode of evolution of the polychaet detailed above—by three ventral invaginations (two great and one small)—would involve, also, as these took place, the contraction and packing together of the dorsal parts of the ventrally invaginated segments and, therefore, of the nuchal ganglia. The tetraneural families, as they retained their podial longitudinal nerves, took advantage also of this, and have incorporated the nuchal organs into the caruncle, and the nuchal ganglia into the brain.

MORPHOLOGICAL SIGNIFICANCE AND RELATIONSHIPS
OF THE PERISTOME

On our theory *the peristome is not a somite* but marks the site of a succession of breaks, causing a gap in an originally continuous sequence of ganglia, the remainder of which form the ventral nerve cord. Further, in the course of evolution the peristome has been extensively exchanged three times over. The missing members are believed to be partly distributed along the visceral nervous system, and partly coalesced with the brain. The magnitude of this "gap" furnishes a complete explanation of the hitherto mysterious fact—that the nervous system arises from two distinct rudiments, one giving rise to the brain, the other to the ventral chain—a fact which has been noted by numerous workers from Salensky (1882) and Goette (1882) onward. The visceral ganglia are thus brought into the succession of those of the central nervous system, in opposition to the generally accepted view of their separate origin. With more detailed knowledge of the visceral nervous system it may be possible to determine in large degree the succession of the various ganglia which can be recognized.

In the brain, besides the fore-brain and hind-brain we have an association of three pairs of comparable ganglia, sending out comparable pairs of nerves, and innervating comparable organs; and according to this theory they were added to the brain at three different times. Further, they were selected by nature in the course of evolution from a considerable length of the primitive ventrolateral nerve cords, including probably well over a dozen pairs of ganglia. The order, too, of the upbuild of the brain on this theory is quite different from that on any other. The contrast between this plan and the others that have been advanced could hardly be greater, whether we compare it with that of Pruvot, or Racovitza, Nilsson, Lameere, or Hanström. The reason for this is that it connects the three systems—the brain, the visceral nervous system, and the stomodeum. It is curious that the order of the elements of the mid-brain happens to be the same as on Lameere's theory; but the significance is entirely different. It may be remarked that there is much to be said in favor of Lameere's theory as a mode of origin of the annelid; not, however, of the polychaet but of its distant ancestor.

Should our theory prove correct, Racovitza will have builded wiser than he knew, though quite other than what he meant; for the primal brain was his fore-brain, to this was added his mid-brain, and to this the hind-brain.

But the evolution of the head and brain envisaged here is entirely

different from that of Racovitza. In his view the peristome did not differ fundamentally from a normal segment (1896, p. 154); the head of the ancestor *became* the head of the polychaet; the parts were already there, including the primal elements of the cerebral nervous system—the “aire palpaire,” “aire sincipitale,” and “aire nucale.” Only further development of these was needed: that of the sense organs on them into palps, antennae, eyes, and nuchal organs; that of the areas themselves into the fore-, mid-, and hind-brains. Before this evolution in the polychaet there were no comparable sensory organs (1896, p. 161). On the contrary, according to the theory here presented, the ancestor was already furnished with eyes and parapodia throughout the body, and possibly also some form of appendages and eyes on the head, which already possessed a brain and bore also an early stage of the mouth-lips. The 4 (or more) pairs of ganglia, too, which initiated the mid- and hind-brains were already functioning in their own postcephalic segments. But whatever sense organs that primitive annelid had on its head, except for the mouth-lips these organs were superseded in the evolution of the polychaet by previously postcephalic eyes and antennae; while its brain was to be extensively supplemented and partially superseded. A fundamental difference between the two views is that Racovitza in evolving the polychaet brain thought he was evolving that of the primitive annelid, whereas on the here offered theory no primitive annelids survive.

APPLICATION OF THE AUTHOR'S THEORY TO POLYCHAETS IN GENERAL

Very close comparisons are now possible between the different families of errant polychaets in regard to the prostomium and its appendages and eyes, the brain, the stomodeum, and the central and visceral nervous system; and, to judge from the results of past research, the suggestions of close affinity are not likely to be diminished in the future. In the accompanying table typical representative sub-orders and families are tabulated in regard to their brain, sense organs, stomodeum, and buccal segments; in it, too, the homologies are indicated, and characterized as succinctly as possible. The agreement in brain and sense organs is extremely close; and even in the stomodeum, though the characteristics vary so much, a series of stages can be seen between the Eunicimorph through the Amphimorph to even the Glycerimorph.

In table 3 the order of development of the different sections of the stomodeum is to some extent indicated by the letters a, b, c; and the order of incorporation of the divisions of the brain by A; BI, BII, BIII; C.

So close are these comparisons that one can have little doubt but that all derive from the same ancestral stock; and if the fundamental plan of the brain above detailed be accepted, it will be agreed that the closest approach to this ancestral stock is to be found in the Eunicimorpha. The evolution which has been traced, if it be substantially true, is therefore that of the ancestral polychaet. It can all be assigned to very far back in pre-Cambrian time, effected say before 1,000 million years ago. Of this the writer feels confident; because, as he hopes to show, the arthropods, some of the classes of which were evolved long before Cambrian time, were derived from a *particular family* of polychaet still extant!

If the above given conclusions as to the character and origin of the original polychaet brain be accepted, its further evolution can with some confidence be pictured. The separate ganglia of the two sides of the brain united in the midline, consolidation was effected, and enormous development has ensued—development which can be read by detailed comparisons of the brains of the various polychaets. The fore-brain, hitherto dominant, has lost its old eminence even in the Eunicidae; and in other families is often greatly reduced. The mid-brain has undergone great development, and perhaps in all forms has become the chief nervous center. And whereas, as is here assumed, the palpal function in the primitive polychaet was seated in the mouth-lips, and served by the fore-brain, now only in the Eunicidae and Amphinomidae is this the case. In some others it is apparently seated in the proboscis and is still served by the fore-brain: in yet others (viz, the Aphroditidae, Chrysopetalidae, Hesinoidae, Syllidae, and Nereidae) the function has been transferred to the anterior pair of antennae, transformed into palps, and is served mainly by the mid-brain. This is indeed the case even in a family of the Eunicimorpha—the Stauronereidae (Staurocephalidae). The degrees of development of the brain are extremely varied; and the new structures include neurone courses, nerves, commissures (transverse in considerable number, and also longitudinal), the true brain ganglia, and in the highest forms the corpora pedunculata. In the Amphinomorpha extra pairs of nuchal ganglia have joined the hind-brain and this has here become much the most voluminous division of the brain. With different modes of life very different lines of evolution were followed. All other suborders seem to have changed more than did the eunicid. Here the brain is still relatively primitive, exhibiting its primitive subdivisions still extended in a plane. In contrast, in the aphroditid it is compact, folded over between front and rear and very highly developed. On the other hand, in some

errant families and perhaps in all the sedentaries it has degenerated.

Regarding the stomodeum, if, as is above suggested, the much-folded form exhibited by the Eunicimorph is the most primitive type, the different errant polychaets present us with suggestions of the stages of evolution between this relatively nonprotrusible folded type and the extremely protrusible cylindrical type of say the Glycerimorpha. Such an evolution one might expect to be accompanied by great changes in the visceral nervous system, and probably also in the brain.

To trace the evolution of any form and the deployment within the class, it will be of great advantage to have a starting point, a basic plan, which is all that the present paper can claim to attempt. Were zoologists to attempt to work out by ontogeny and by comparative anatomy the many courses of evolution within the class, the common starting point would soon be apparent.

TABLE 3.—Comparison of supposed homologues of the morphological entities of the head region of typical errant polychaets (pelagic families omitted)

Divisions of head region	Prostomium: front and venter	Prostomium: dorsum	Prostomium: rear	Stomodaeum	Peristome	Accessory buccal segments
Corresponding brain divisions	A Fore-brain in-ner-ving a pair of anterior lips	BII Median brain in-ner-ving a pair of tentacles and a pair of eyes	C Hind-brain in-ner-ving the <i>nuchal organs</i>			
POLYCHAET suborders and families	Anterior lips with no defined organs	Median tentacle vestigial (<i>S. rabyra</i> Verrill) or absent	One pair of nuchal furrows, each subdivided into 2 pits	(c) pair of plates, toothed at free edge (b) 2 or more series of very numerous teeth on each side, all paired Bilateral symmetry	Rather large No appendages	1 segment No appendages
EUNICMORPHA Stauronereidae (Stauronerepidae) Dorvilleidae Stauronereis (Stauronerepulus)	Pair of anterior mouth-lips, so-called "palps" (Gustafson)	Median tentacle Eyes rare	One pair under front of peristome	(c) pair of plates (b) 2 or more series of very numerous teeth on each side, all paired Bilateral symmetry	Very large No appendages	1 segment One pair of tentacular cirri or none
Eunicidae (Leodicidae)	Outside tentacles (palps of Racovitza)	Intermediate tentacles Eyes	Supreme development into caruncle extending over anterior segments, ganglia of the hind brain	(c) lower jaw sack, with bilaterally unsymmetrical armor (a) long oesophagus	Peristome little differentiated, and bearing parapodia. Primitively, as in <i>Paromphiphothe</i> , the mouth is surrounded by the peristome and has the first ventral ganglia with their commissure behind it. But within the family the mouth opening has suffered great increase of size and rearward migration; and usually the second ventral commissure is the first behind it, the first being apparently broken.	None
AMPHINOMORPHA Amphinomidae	Lateral and anterior mouth-lips (palpophore of Racovitza)	Intermediate tentacles (or absent) Large eyes (or absent)	Supreme development into caruncle extending over anterior segments, ganglia of the hind brain	(c) lower jaw sack, with bilaterally unsymmetrical armor (a) long oesophagus	Peristome little differentiated, and bearing parapodia. Primitively, as in <i>Paromphiphothe</i> , the mouth is surrounded by the peristome and has the first ventral ganglia with their commissure behind it. But within the family the mouth opening has suffered great increase of size and rearward migration; and usually the second ventral commissure is the first behind it, the first being apparently broken.	None

TABLE 3—Continued

Polychaet suborders and families	Fore-brain	Mid-brain III	Mid-brain II	Mid-brain I	Hind-brain	Stomodaeum	Armour	Peristome	Accessory buccal segments
Нереймообразные Phyllodoctidae	No defined organs	Tentacles	Tentacles Eyes	Median tentacle (or absent) Eyes (or absent)	Primitive nuchal organs	Protrusible proboscis (c) eversible protrusible sheath pharynx in 2 sections (a) ventricle often with 2 caeca	(c) with papillae and sometimes paragnaths Almost cylindrical symmetry	Peristome with one or two pairs of tentacular cirri	One or two other segments may bear only tentacular cirri
Нерейды	No defined organs	Tentacles (anterior)	Tentacles (posterior) Eyes	Absent Absent	Present (according to Pruvot, 1885)	Short protrusible proboscis (c) eversible sheath (b) pharynx in two stages (a) ventricle	(c) papillae in longitudinal sections, and adjoining pharynx (b) 2 short horny jaws or none Bilateral symmetry	Peristome fused with next segment No cirri	
Нерейды	No defined organs	Large palps each with 2 "joints"	Tentacles Large eyes	Absent Smaller eyes	Nuchal organs	Strong protrusible proboscis (c) eversible muscular sheath (b) pharynx with massive muscles (a) oesophagus or ventricle with 2 caeca	(c) with papillae and with teeth (paragnaths) (b) transverse jaws in front, and muscle ridges behind Bilateral symmetry	Peristome coalesced with next segment, each bearing 2 pairs (dorsal and ventral) of tentacular cirri. They may bear parapodia with setae	
Несомиды	No defined organs	Palps 2-jointed (absent only in <i>Hestione</i>)	Tentacles Eyes	Median tentacle (or absent) Eyes	Primitive nuchal organs	Strong, very extensible protrusible proboscis (c) eversible sheath (b) muscular pharynx (a) ventricle, with a pair of caeca	(b) with papillae, and with or without horny jaws Bilateral almost cylindrical symmetry	Peristome with 2 pairs of tentacular cirri, with a bundle of bristles at base of each	10-3 segments without setae may be separate, or coalesced with the peristome, each with 2 pairs of tentacular cirri

TABLE 3—Continued

Polychaet suborders and families	Fore-brain	Mid-brain III	Mid-brain II	Mid-brain I	Hind-brain	Stomodaeum	Armour	Peristome	Accessory buccal segments
Syllidae	No defined organs	Greatly developed palps, much jointed	Tentacles Eyes	Median tentacle Eyes (2 extra pairs may be present drawn from rear)	Nuchal organ present according to Spengel, 1881	Long, protrusible proboscis (c) eversible sheath (b) protrusible cylindrical pharynx followed by barrel-form proventricle (a ₂) (a ₁) postventricle with or without a pair of caeca	(b) with 1 dorsal tooth or several, and with papillae Bilateral, almost cylindrical symmetry	Peristome with 1 or 2 pairs of tentacular cirri but no setae	None
APHRODITIDAE Polynoidae	No defined organs	Long palps	Tentacles (or absent) Eyes	Median tentacle (or absent) Eyes	Nuchal organ	Cylindrical, protrusible proboscis (c) eversible sheath (b) protrusible pharynx (a) ventricle	(b) with a circle of papillae and a pair of dorsal and 4 pair of ventral jaws Bilateral symmetry	Peristome with 2 pairs of tentacular cirri with setae at the base	Ventral cirrus of next segment very long
GLYCERIMORPHA Glyceridae	Extremely modified, represented by the venter of the conical secondarily annulated prostomium. (Hansson, 1927)	Lower tentacles at end of prostomium	Upper tentacles at end of prostomium No eyes usually absent	Absent Absent	Nuchal organ	Long cylindrical or clavate far-protrusible proboscis (c) eversible sheath (b) muscular protrusible pharynx (a) ventricle	(c) covered with papillae (b) with 4 jaws or 2 jaws and numerous paragnaths Almost cylindrical symmetry	Peristome with no appendages	None

CONCLUSION

Both in their complexly folded stomodeum and in their brain the Eunicimorpha are claimed as the most primitive of polychaets. Their study suggests the characters of the ancestral annelid and the subsequent evolution of the complexities of the stomodeum, the brain, and the visceral nervous system of the polychaet.

In brief, on this view, the ancestors of the polychaet, in connection with their successive modes of feeding, transferred not only the external skin, but also the nerves and ganglia of the central nervous system, which at that time were lateral in position, and also the appendages associated with those ganglia, up the alimentary tract in the formation of the stomodeum. As a primary result they have originated (or greatly added to) their visceral nervous system; and as a secondary result have complicated their brain. The dominating factors were the invaginations; and the structure of the eunicid shows that these took place three times over. (An analogous process took place yet again in the evolution of arthropods, as the writer hopes to show.)

Most of the fundamental ideas expressed in this paper are already summarized on pp. 19 to 27.

Though the evolution here claimed is so great and so widespread, it is not believed to be beyond the capacities of variation and natural selection to effect.

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A NEW HERON AND A NEW OWL
FROM VENEZUELA

BY

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A NEW HERON AND A NEW OWL FROM VENEZUELA

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Among a collection of birds from northeastern Venezuela is a specimen of an adult male *Syrigma sibilatrix*, the whistling heron. At first glance this bird was seen to be strikingly different from a good series from southern Brazil, Paraguay, and Argentina, especially in the coloration of the upper wing coverts, but also of the crown, neck, breast, and, less obviously, in size. As no name appears to be available for this bird, I take pleasure in naming it for the collector.

SYRIGMA SIBILATRIX FOSTERSMITHI, new subspecies

Type.—U.S.N.M. 406385, ad. ♂, Caicara, Monagas, Venezuela, July 24, 1948, collected by Foster D. Smith, Jr. (orig. No. 143).

Subspecific characters.—Similar to the nominate race but differs in having the upper wing coverts much more yellowish and more narrowly striped with black—between chamois and honey yellow, not dull pinkish cinnamon to light ochraceous salmon as in the southern birds; the neck and breast more yellow, less olivaceous—light honey yellow, not light buffy olive as in typical *sibilatrix*; crown somewhat paler—slate color (blackish slate in the nominate race) and with the bill longer, culmen 74.1 mm. as against 66-71 mm. in southern birds.

Measurements of type.—Wing 280, tail 105, culmen from base 74.1, tarsus 88.2 mm.

Range.—I have seen only the type, from Caicara, Monagas, but Hellmayr and Conover (Cat. Birds Amer., pt. 1, No. 2, p. 207, 1948), state that the species (undoubtedly this race) occurs in the valleys of the Orinoco and Apure Rivers in Venezuela. In a footnote they write that it “. . . remains to be ascertained by the study of an adequate series whether Venezuelan birds are really quite the same [as birds from southern Brazil south to Argentina]. A single adult from the Río Apure is slightly larger with longer tarsus and bill, while the upper wing coverts are more predominately yellowish and more narrowly streaked with blackish. The divergencies are, however, insignificant.” How they could call a striking color difference insignifi-

cant is beside the point; their Río Apure bird is obviously of the northern, yellow-winged race. When first reporting this specimen, Berlepsch (Ibis, 1884, pp. 438-439) noted that it agreed with others from southeastern Brazil, but had the bill longer, and broader at the base, and that the ". . . upper wing coverts are more yellowish, not so much mixed with brownish, and the black stripes on them thinner and finer."

The species, then, has two races, which are widely separated geographically, as follows:

Syrigma s. sibilatrix—southern Brazil, Uruguay, Paraguay, Bolivia, and northern Argentina.

Syrigma s. fostersmithi—north-central and northern Venezuela.

At Cantaura, July 13, 1947, Mr. Smith collected an adult male short-eared owl in good plumage. No short-eared owl was previously known to occur in northern South America east of the high páramo zones of Colombia and Ecuador, and it is not surprising to find that the one collected differs sufficiently from all the described forms to warrant giving it a name.

ASIO FLAMMEUS PALLIDICAUDUS, new subspecies

Type.—U.S.N.M. 406386, ad. ♂, Cantaura, Anzoátegui, Venezuela, July 13, 1947, collected by Foster D. Smith, Jr. (orig. No. 20).

Subspecific characters.—Resembling *A. f. bogotensis* Chapman of Colombia-Ecuadorian highlands in its general dark color above, but differing from that race in having the ochraceous buffy markings on the back somewhat more extensive, in having a strikingly paler tail, the central rectrices being light ochraceous buff barred broadly with fuscous, the pale and the dark bands about equal in width (the dark ones very much wider than the pale ones in *bogotensis*) and the lateral rectrices similar with the dark bars rapidly decreasing in width, becoming narrow bars on the inner webs of the outermost pair and entirely absent on the outer web of the outermost pair (the median rectrices in *pallidicaudus* are about like the outer ones in *bogotensis*), the facial disc more tinged with ochraceous buff, the breast less heavily streaked with fuscous, the under wing coverts almost immaculate ochraceous buff (much streaked with fuscous in *bogotensis*) and the outermost primaries with fewer bands on the underside, unbarred for the basal two-thirds (in *bogotensis* less than two-fifths).

Measurements of type.—Wing 304, tail 140, culmen from base 30, tarsus 52 mm.

Range.—Known only from the type locality.

In his review of the neotropical short-eared owls, Bangs (Proc. New England Zool. Cl., vol. 6, pp. 95-98, 1919) rightly criticizes the tendency in literature to give the American range of the bird as North and South America from the Arctic Ocean to Patagonia, and goes on to say that he “. . . can find no record for the short-eared owl from anywhere in southern Central America, nor in the vast forested regions of northern South America. Even in migration North American birds range only about as far as Guatemala and Cuba. In South America, except for the very distinct local form (*bogotensis*) . . . the short-eared owl is confined to the open regions, south of the forest, in temperate southern South America. . . .” The new race described in this paper is the first evidence of a connecting link in the open areas of Venezuela.



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A COLLECTION OF FISHES
FROM TALARA, PERÚ

BY
SAMUEL F. HILDEBRAND
AND
OTIS BARTON



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A COLLECTION OF FISHES FROM TALARA, PERÚ

BY SAMUEL F. HILDEBRAND¹ AND OTIS BARTON²

An unusually interesting collection of fishes was obtained at Talara, Perú, from January to April, 1946, by the junior author. Two new species from this collection have already been described (Barton, 1947), and descriptions of seven others are included in these pages. In addition to the apparently new forms, three species previously not reported from Perú are included. Descriptions of these species also are offered herein, as the present paper is to serve as a supplement to "A Descriptive Catalog of the Shore Fishes of Peru" (Hildebrand, 1946). Most of the specimens were obtained from fishermen who fished on the banks west of Talara, at depths down to 250 feet. The carefully executed drawings of the new species herein described were made by Mrs. Ann S. Green of the U. S. Fish and Wildlife Service. The paper was prepared in the Division of Fishes, United States National Museum.

Family ALBULIDAE: Ladyfishes; Bonefishes

Body elongate, little compressed; head rather low, flat above; snout conic, projecting far in advance of lower jaw; mouth moderately small, nearly horizontal; maxillary reaching nearly to front of eye or below it, never beyond eye; premaxillaries not protractile; no gular plate; teeth all small, present in bands on jaws, vomer, palatines, pterygoids, basibranchials, and sphenoid; branchiostegals 13 or 14; gill membranes separate and free from the isthmus; gill rakers very short, stout, tubercular in large examples; lateral line straight; scales rather small, with membranous borders, not extending on head, a modified row on back in front of dorsal fin; dorsal fin beginning in advance of ventral fins; caudal fin forked; anal fin very small, far behind dorsal; ventral and pectoral fins similar, each with an axillary scale.

¹ Ichthyologist, United States Fish and Wildlife Service. Dr. Hildebrand died on March 16, 1949, before this paper went to press.

² Explorer.

Genus *ALBULA*

This genus differs from *Dixonina*, the only other genus of the family, chiefly in the last ray of the dorsal and anal being short; not produced and filamentous as in *Dixonina*. Other characters are included in the description of the family.

ALBULA VULPES (Linnaeus)

Esox vulpes LINNAEUS, 1758, ed. 10, p. 313, Bahama Islands. (Diagnosis, based on *Vulpes bahamensis* Catesby, pre-Linnaeus.)

Albula vulpes JORDAN and EVERMANN, 1896, p. 411, fig. 179 (description; synonymy); Meek and Hildebrand, 1923, p. 179 (synonymy; description).

Head 3.0, 3.4; depth 4.9, 5.0; eye 4.2, 4.0 in head; snout 3.1, 2.8; maxillary 3.0, 2.9; interorbital 5.25, 5.5; caudal peduncle 4.1, 4.0; anal base 4.5, 5.1; ventral fin 2.2, 2.3; and pectoral fin 6.2, 6.7. D. 17, 17; A. 8, 8; P. 16, 17; scales 70, 70; gill rakers 7+11, 9+12.

Two young adults, 68 and 80 mm. in total and 55 and 64 mm. in standard length are included in the collection. The proportion or enumeration given first in each instance pertains to the larger specimen. The family and generic characters, together with the data given in the preceding paragraph are sufficient to identify the species. These specimens retain the dark cross bands on the back of the juvenile, which generally disappear at about the length attained by the larger specimen.

Range.—Reported from nearly all warm seas: On the Pacific coast of America from Monterey Bay, Calif., southward to Panamá Bay, and now to northern Perú; and on the Atlantic from Woods Hole, Mass., to Rio de Janeiro, Brazil.

Family MURAENIDAE: Moray eels

PRIODONOPHIS EQUATORIALIS Hildebrand

Priodonophis equatorialis HILDEBRAND, 1946, p. 134, fig. 31, Cabo Blanco, Perú (original description).

A single specimen, 490 mm. in total length, is included in the collection. It, in general, agrees very well with the holotype and a paratype of this species. Minor differences are evident, however, from a comparison of the specimens. The skin seems to be thinner and smoother in the Talara specimen, which may be the result of different methods of preservation, or possibly of a difference in age, as this specimen is smaller than the type and paratype. One eye in the Talara specimen definitely is smaller (probably abnormal) than in the type specimens, but the other one is larger and just about bridges the gap. There seems to be virtually complete agreement in the size and shape

of the teeth, which are in a single series in each jaw, have broad bases, are flattened, and have definite serrations at least on the posterior margins. However, the Talara eel has two small teeth on the median line far back on the roof of the mouth, which are missing in the other specimens. In color the Talara specimen is darker brown than the other specimens, and it has fewer pale spots than the holotype, but more than the paratype, becoming larger on the distal part of the tail than in the other specimens. The differences indicated are regarded as variations within the species.

Range.—Northern Perú, from off Mount Organos and from Talara.

PRIODONOPHIS SERRATIDENS, new species

FIGURE 1

Body with smooth skin, somewhat compressed, its thickness at vent about four-fifths of its depth at same place; tail more strongly compressed, tapering to a rather narrow point; length anterior to vent slightly greater than length posterior to vent, 1.9 in total length; head more strongly compressed than body, its width just in front of gill opening equal to about half its depth at the same place, its length anterior to gill opening 8.3 in total length and 4.25 in length anterior to vent; greatest depth (at gill opening) 6.8 in length anterior to vent, 1.6 in head; snout moderately robust, rather broader than deep in cross section, 5.1 in head; eye small, 12.2 in head, 2.4 in snout; mouth large horizontal, the gape extending about half its length beyond middle of eye, 2.25 in head; lips with small papillae; upper lip and lower jaw with prominent pores; teeth in jaws in a single series, definitely compressed, with rather broad bases, and with both margins strongly serrated, none on vomer, though present in a single series far back on shaft (see insert, fig. 1) and none on palatines; anterior nostril with a tube about two-thirds length of eye, situated well above margin of lip, posterior nostril a round pit, situated at dorsal edge of snout, a little in advance of vertical from anterior margin of eye; gill opening an oblique slit, about 1.5 times length of eye; vertical fins very low, especially anteriorly, not incased in thick skin, fully confluent around the tail, the origin of dorsal a little in advance of gill opening, its origin to tip of snout 4.2 in length anterior to vent; caudal fin rather broadly rounded.

General ground color brown; sides of head with dark brown longitudinal stripes, extending on anterior part of body, becoming cross lines and reticulations below and somewhat behind gill opening; upper surface of head and body everywhere, except on ventral surface of head and trunk, with pale spots, mostly larger than eye, extending more or less on the dorsal and anal fins; dorsal fin with an intra-

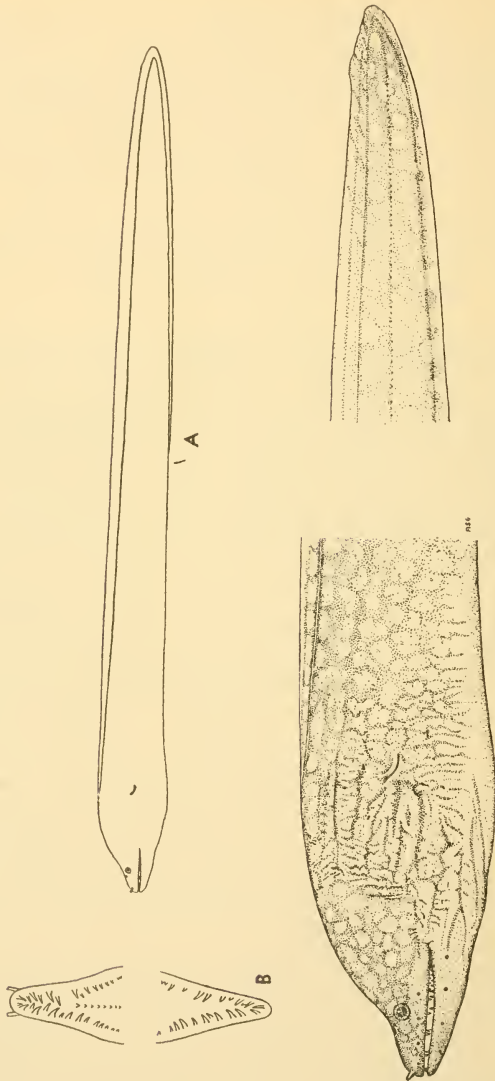


FIG. 1.—*Priodonophis serratidens*. From the type, 510 mm. long, Talara, Perú (U.S.N.M. No. 144253). A, diagram showing shape and proportions; B, mouth spread open showing teeth.

marginal pale streak anteriorly, becoming marginal over the mid-caudal section, soon fading into the general pale brown color of the posterior section of the fin.

This species is represented by a single specimen (U.S.N.M. No. 144253) 510 mm. in total length. Its chief distinguishing characters are shown in the parallel comparison of the three species of this genus herein recognized, which follows the description of *P. angusticeps*.

The name *serratidens* is in reference to the serrated teeth in the jaws.

PRIODONOPHIS ANGUSTICEPS, new species

FIGURE 2

Body with wrinkled skin, compressed, its thickness at vent a little less than three-fourths its depth at same place; tail more strongly compressed, becoming strongly compressed and broadly rounded distally; length anterior to vent equal to length of rest of body; head deep, rather strongly compressed, its width just in front of gill opening equal to about half its depth at same place, its length anterior to gill opening 6.4 in total length and 3.25 in length anterior to vent; greatest depth (at gill opening) 6.6 in length anterior to vent, 2.0 in head; snout fairly robust, not much deeper than broad, about square in cross section, 6.1 in head; eye small, 11.4 in head, 1.85 in snout; mouth very large, horizontal, the gape extending about half its length beyond middle of eye, 2.3 in head; lips with small papillae; upper lip and lower jaw with prominent pores; teeth in jaws in a single series, rather small, not prominently compressed, with finely serrated margin visible only under magnification, none on vomer or palatines; anterior nostril with a tube about two-thirds length of eye, situated well above margin of upper lip, posterior nostril a roundish pit surrounded by a slightly raised membrane, situated near edge of dorsal surface of snout just in advance of vertical from anterior margin of eye; gill opening an oblique slit, nearly twice diameter of eye; dorsal fin high, more than twice as high as the anal, its greatest height about equal to length of snout and eye, fully confluent with the caudal and anal, its origin from tip of snout 4.9 in length anterior to vent; caudal fin broadly rounded.

General color rather light chocolate brown, the furrows of the wrinkled skin dark brown, mostly horizontal on head and vertical on body, some wavy or even slightly cross hatched, disappearing on distal part of tail; fins of about same color as body, dark lines following the furrows of the wrinkles in the skin, paralleling the rays.

This apparently new eel is represented in the collection by a single specimen (U.S.N.M. No. 144254), 510 mm. in total length. The

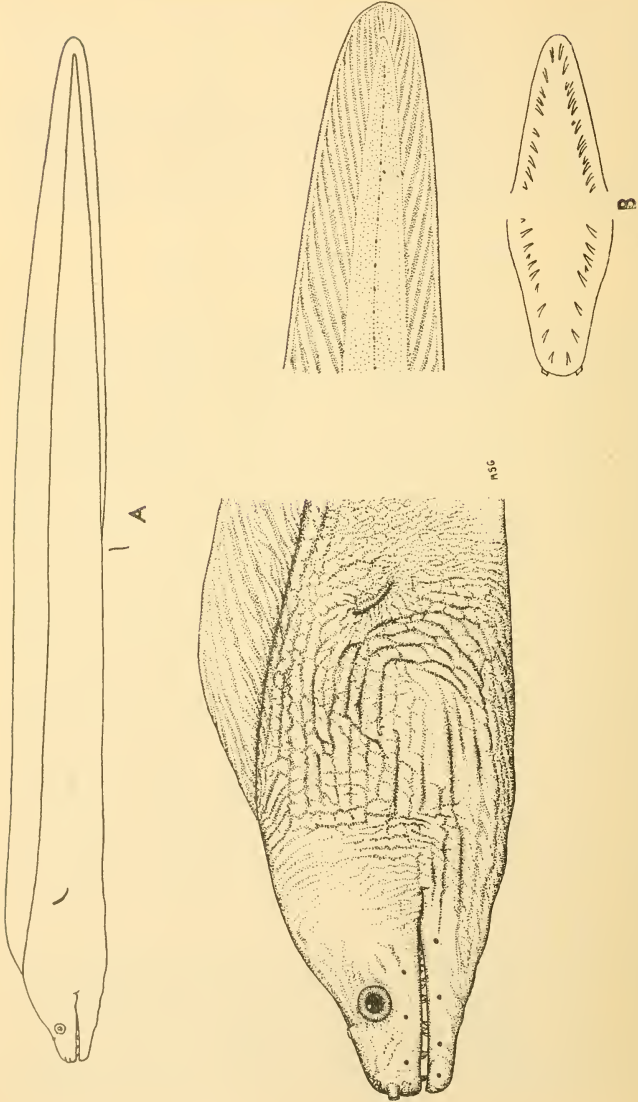


FIG. 2.—*Priondonophis angusticeps*, new species. From the type, 510 mm. long, Talara, Perú (U.S.N.M. No. 144254). A, diagram showing shape and proportions; B, mouth spread open showing teeth.

principal differences among the three species of this genus, recognized in these pages, are shown in the parallel comparison that follows.

The name *angusticeps* was suggested by the rather narrow compressed head.

<i>equatorialis</i>	<i>serratidens</i> , new species	<i>angusticeps</i> , new species
Teeth in jaws compressed, with broad bases, the posterior margin of each tooth always and the anterior margin generally serrate.	Teeth in jaws compressed, with broad bases, each margin of tooth definitely serrate.	Teeth in jaws little compressed, with minute serrae, present only at base of most of the teeth.
Skin on body mostly smooth, wrinkles if present not extending on dorsal fin.	Skin on body and fins smooth.	Skin on body very wrinkled, the wrinkles extending on dorsal fin.
Head and trunk definitely shorter than tail, length anterior to vent 2.3 in total length.	Head and trunk about equal to length of tail.	Head and trunk about equal to length of tail.
Head large, its length to gill opening 3.0 in length anterior to vent, 6.8 in total length.	Head small, its length to gill opening 4.25 in length anterior to vent, 8.3 in total length.	Head moderately large, its length to gill opening 3.25 in length anterior to vent, 6.4 in total length.
Snout about square in cross section, 6.0 in head.	Snout rather broader than deep in cross section, 5.1 in head.	Snout a little deeper than broad in cross section, 6.1 in head.
Origin of dorsal well in advance of gill slit, its distance from tip of snout 4.1 in length anterior to vent, 9.4 in total length.	Origin of dorsal little in advance of gill slit, its distance from tip of snout 4.2 in length anterior to vent, 8.2 in total length.	Origin of dorsal far in advance of gill slit, its distance from tip of snout 4.9 in length anterior to vent, 9.6 in total length.
Dorsal fin rather low, its height nowhere exceeding length of snout, not enveloped in thick skin.	Dorsal fin very low, its greatest height about half length of snout, enveloped in thin skin.	Dorsal fin high, its greatest height about equal to length of snout and eye.
Head and body with pale spots, very small (dots) on head, becoming larger posteriorly, all smaller than eye.	Head and body with much larger pale spots, many of them equal to or larger than eye.	Head and body unspotted, but with dark lines in the furrows of the wrinkled skin.

Family GADIDAE: Codfishes

Body generally quite elongate, tapering toward the tail; mouth large, terminal or more usually inferior; chin with a barbel; gill openings wide; gill membranes separate or somewhat united, generally free from the isthmus; gills 4, a slit behind the fourth; vent generally more or less median in position; air bladder rarely missing in adults; scales small, cycloid; fins without spines; dorsal fin generally occupying nearly the full length of back, single or divided into 2 or 3 sections; caudal fin separate or united with the dorsal and anal; anal fin long, single or divided into 2 parts; ventral fins jugular, each consisting of 1 to 8 rays.

This is a large family, which includes many important food fishes. In tropical regions it is represented by species inhabiting deep water.

Genus *PHYSICULUS* Kaup, 1858

Body elongate, robust anteriorly, tapering sharply posteriorly; head large, generally more or less depressed; mouth broad, more or less inferior; snout broad; chin with a short barbel; teeth in jaws in villiform bands, none on vomer or palatines; scales small, extending forward on snout and on chin; dorsal fins 2, the first one small; caudal fin round, free from dorsal and anal; anal fin single; ventral with 5 to 7 rays, the outer ones more or less filamentous.

About seven species are known from off the American coasts, generally living in rather deep water.

PHYSICULUS TALARAE, new species

FIGURE 3

Head 3.85; depth 4.6; D. 10-60; A. 63; P. 26 and 27; scales partly lost, about 110.

Body robust anteriorly, tapering sharply and becoming rather strongly compressed posteriorly, its depth at base of pectorals scarcely an eye's diameter greater than its width at the same place; caudal peduncle very slender, strongly compressed, its depth 11.5 in head; head rather large, a little broader than deep at margin of preopercle, its depth at this point 5.5 in standard length; snout low and broad, 4.1 in head; eye moderate, 4.4; interorbital flat, 4.75; mouth rather large, its gape about as broad as long; lower jaw definitely shorter than the upper one, included; maxillary almost reaching vertical from posterior margin of eye, 1.9 in head; teeth in jaws in villiform bands,

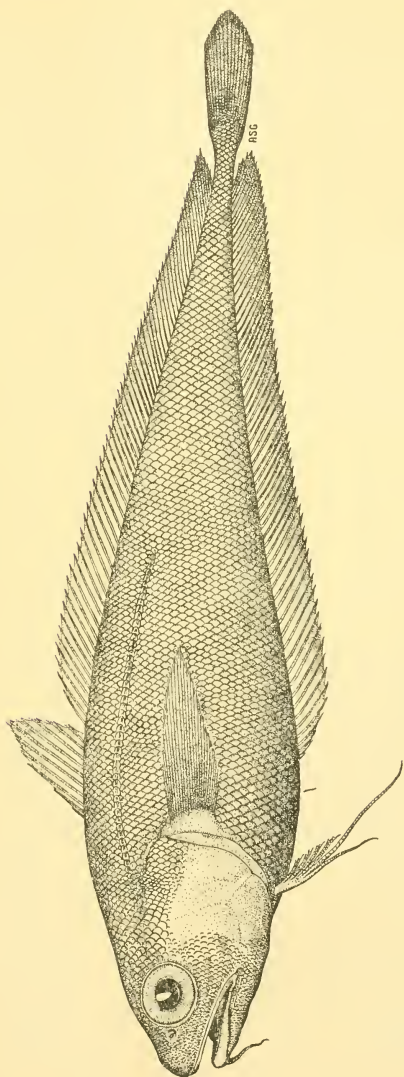


FIG. 3.—*Physiculus talarae*, new species. From the type, 265 mm. long, Talara, Perú (U.S.N.M. No. 144355).

the one in upper jaw the broader, mostly exposed with mouth closed; preorbital scarcely as broad as pupil; gill rakers short, expanded at tips, spiny, 12 on lower limb and 4 on the upper one of first arch; lateral line incomplete, ending near midbody length, or about 2 diameters of eye behind tip of pectoral, with a long low arch anteriorly, being highest under origin of second dorsal; scales small, extending forward to margin of snout and on chin, but not on fins except on base of caudal, 8 longitudinal rows between lateral line and middle of first dorsal; dorsal fins 2, definitely separate, the first short, more or less triangular in shape, its middle rays longest, 2.33 in head, the second long and low, with a straight margin; caudal fin small, round, about as long as snout and half the eye; anal fin similar to second dorsal; ventral fin narrow, with 6 rays, the outer rays produced, the second the longest, reaching about an eye's diameter beyond origin of anal, but failing to reach tip of pectoral by about an equal distance, definitely shorter than head, 5.3 in standard length; pectoral rather large, pointed, shorter than head, 5.3 in standard length.

Color uniform gray, except for underneath surface in advance of origin of anal which is darker brown; margin of gill covers quite dark; dorsal pale, with a brownish margin; caudal rather darker brown than body, anal similar to dorsal, except that it has a darker margin; ventral dark at base, otherwise colorless; pectoral brownish like the body.

This apparently new species is represented by a single specimen (U.S.N.M. No. 144255), 265 mm. in total and 243 mm. in standard length. It seems to be nearest *P. nematopus* Gilbert, known from many specimens taken at depths ranging from 71 to 221 fathoms in the Gulf of California, of which five "type" specimens, 78 to 147 mm. in total length (U.S.N.M. No. 46555), are at hand for comparison. The most outstanding difference between those specimens and the one from Perú is the difference in the number of pectoral rays. This and other differences are shown in the parallel comparison that follows. Some of the other differences, consisting of proportions such as the depth of the body and the length of the ventral fins, may be affected by age and growth, and therefore are not entirely reliable.

Another closely related species is *P. longipes*, known from specimens taken in 127 to 695 fathoms in Panamá Bay or in the vicinity thereof, of which one of the "type" specimens, 113 mm. in total length (U.S.N.M. No. 57876), is at hand. The Peruvian specimen differs from this one in the greater number of pectoral rays, just as

it does from *nematopus*, but it agrees in the depth of the body and more or less in the length of the head. These and other differences are shown in the parallel comparison. The validity of this species, that is, its distinctness from *nematopus*, has been questioned by Norman (1937, p. 56). In view of the present study it seems advisable to retain *nematopus* and *longipes* as distinct species. Garman (1899, p. 189) stated that *longipes* differs from *nematopus* in having a greater number of dorsal rays and a smaller number of ventral rays. All specimens of 4 species examined have uniformly 6 ventral rays, and the difference in the number of dorsal rays is at most very small, and instead of being more numerous, they actually are slightly fewer according to the specimens examined.

The only other species of this genus reported from off the Pacific coast of tropical America, *rastrelliger*, of which several "type" specimens are at hand (U.S.N.M. No. 44281), differs from all the others of that region in having more gill rakers, 18 to 20 being present on the lower limb of the first arch.

<i>nematopus</i>	<i>longipes</i>	<i>talarae</i> , new species
Pectoral rays 20 to 23.	Pectoral rays 20 and 21.	Pectoral rays 26 and 27.
Dorsal rays 10-56 to 59.	Dorsal rays 11-54.	Dorsal rays 10-60.
Scales in lateral series 86 to about 100, and 6 longitudinal rows between lateral line and middle of first dorsal.	Scales in lateral series lost in part, about 76, and 6 longitudinal rows between lateral line and middle of first dorsal.	Scales in lateral series lost in part, about 110, and 8 longitudinal rows between lateral line and middle of first dorsal.
Ventral fin longer than head, 3.0 to 3.55 in standard length.	Ventral fin longer than head, 3.3 in standard length.	Ventral fin shorter than head, 5.3 in standard length.
Head moderate, its length 3.9 to 4.0 in standard length.	Head large, its length 3.5 in standard length.	Head moderate, its length 3.8 in standard length.
Depth 5.1 to 5.25 in standard length.	Depth 4.7 in standard length.	Depth 4.6 in standard length.
Eye 3.4 to 4.1 in head.	Eye 4.65 in head.	Eye 4.4 in head.
Gill rakers blunt, not definitely expanded at tips, quite spiny, nearly as long as pupil.	Gill rakers pointed, not expanded at tips, not very spiny, nearly as long as pupil.	Gill rakers broad, greatly expanded at tips, very spiny, scarcely half length of pupil.

Family SERRANIDAE: Seabasses

Genus ANTHIAS Bloch, 1792

Body oblong, compressed; mouth large; premaxillaries protractile; maxillary exposed, covered with scales, with a supplemental bone; teeth in jaws villiform, intermixed with canines, a triangular patch on vomer and an elongate one on palatines, a few or none on tongue; gill rakers long and slender; preopercle serrate, without antrorse spines; lateral line complete, running close to dorsal outline, abruptly decurved under last rays of dorsal; scales covering head and body, smooth or ctenoid; dorsal fin X, 12 to 18; anal fin III, 6 to 8; pectoral fin about 17 or 18; ventral fin long, inserted under base of pectoral, I, 5.

This genus was not represented in the collections on which U. S. National Museum Bulletin 189, 1946, was based. However, Mr. Barton obtained two specimens from fishermen at Talara, Perú, from January to April, 1946, which he described (1947, p. 2) under the name *Holanthias sechurae*. It seems now, however, that the nominal genus *Holanthias* is not well founded, and that it is advisable to refer the species to the genus *Anthias* for the present, along with other related American species.

This genus, although widely distributed in tropical and temperate seas, until recently was known from the Western Hemisphere from only one species reported from the Atlantic coast of South America. Two very closely related species were described recently from the eastern Pacific, one from off Cape San Lucas, México, and the other from Talara, Perú.

ANTHIAS SECHURAE (Barton)

FIGURE 4

Holanthias sechurae BARTON, 1947, p. 2, fig. 2, Talara, Perú (description, based on the holotype, 235 mm. in total length (A.M.N.H. No. 17082), and a paratype 192 mm. in total length).

Head 3.1; depth 3.1; D. X, 15; A. III, 7; P. 19; scales 55 or 56, 52 or 53 in lateral line.

Body rather deep, compressed, dorsal outline more strongly convex than the ventral; snout a little longer than eye; eye 4.0 in head measured to tip of opercular spine; interorbital 4.0; mouth oblique; lower jaw projecting; maxillary extending just beyond center of eye, its greatest width two-thirds diameter of eye; tongue with a considerable patch of fine granular teeth; upper jaw anteriorly with small canine teeth; lower jaw with similar teeth anteriorly and lat-

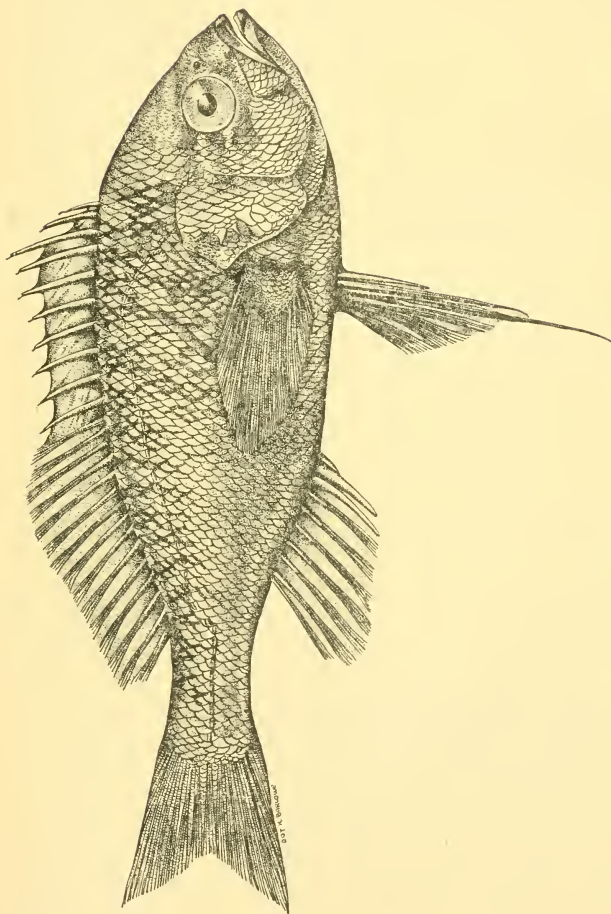


FIG. 4.—*Anthias sechurae* (Barton). From the type, 235 mm. long, Talara, Perú (A.M.N.H. No. 17082).
(After Barton, 1947.)

erally, the anterior ones projecting obliquely forward; preopercle finely serrate, the paratype with two small flat spines at angle in addition to fine serrations on vertical margin; opercle with three spines, the middle one the largest; gill rakers long, slender, 26 on lower limb of first arch; lateral line running close to back, abruptly decurved under last rays of dorsal, thence a little below middle of caudal peduncle to base of caudal fin; scales present on head and body, exclusive of premaxillary, and upper border and tip of mandible; dorsal fin beginning above middle of opercle, the spines increasing in length to the third, then slowly decreasing, the third spine 2.3 in head; soft dorsal with gently convex margin, middle rays longest, no notch between spinous and soft portions; caudal forked, the outer rays not produced; anal fin small, its origin a little behind vertical from beginning of soft part of dorsal, its first spine short, the second one nearly as long as the third, and stronger; ventral fin with first and second soft rays filamentous, the second the longer, extending about to end of anal base; pectoral with narrowly rounded margin, extending a little beyond origin of anal, 1.2 in head.

Color of type "masked by purple stain." Paratype, "yellowish with brown mottling above, a little paler below, fins all pale. It shows traces of three radiating dark lines behind the eye, each line about as wide as pupil, a dark patch between the eyes extending onto snout, and a dark line in front of the eye carried onto tip of lower jaw." (Reorganized and largely reworded after Barton's description and figure.)

This species was described by Mr. Barton, as shown above, from two specimens, the type 235 mm. in total and 188 mm. in standard length, and a paratype 192 mm. in total length, both from the vicinity of Talara (exact place of collection uncertain), Perú. It already has been pointed out by John T. Nichols in a footnote in Mr. Barton's paper that this species is close to *Anthias gordensis* Wade (1946, p. 225). *A. gordensis* was described from two small specimens, 127 and 129 mm. in standard length, taken at 70 to 78 fathoms on Inner Gorda Banks, off Cape San Lucas, México.

Whether *sechurae* and *gordensis* actually are distinct cannot be definitely determined from the published accounts. The number of fin rays and gill rakers, indeed, are virtually the same in the two, but a slight difference in the number of scales in a lateral series is indicated, 55 or 56 being given for *sechurae* and 48 to 50 for *gordensis*. It is not stated, however, exactly where and how the enumerations were made. The eye may be a little smaller in *sechurae*, 4.0 in head, than in *gordensis*, 3.61 and 3.75 in head, but then the specimens of

sechurae are larger. The snout was described as a little longer than the eye in *sechurae* and as shorter than the eye in *gordensis*. The teeth on the tongue were described as granular and as in a "considerable patch" in *sechurae*, and as blunt, few and scattered in *gordensis*. According to the figures the lobes of the caudal are pointed in *sechurae* and about as long as the head without the snout, whereas they are rounded and almost as long as the head in *gordensis*. Although the number of anal rays was given as equal in the two species, the illustrations show the base to be shorter than the soft dorsal by 5 rays in *sechurae*, and by only 2 rays in *gordensis*. Furthermore, the mouth is shown as notably more oblique in *sechurae* than in *gordensis*. In view of these several apparent differences the two may be regarded as distinct at least until further evidence is obtained.

This species, as well as *A. gordensis*, differs from *A. asperilinguis* from the Atlantic coast of South America in having a more elongate body, smaller scales, longer snout, smaller eye, and in the absence of filaments on the outer rays of the caudal.

Range.—Known only from the vicinity of Talara, Perú.

Family PRIACANTHIDAE: Bigeyes

Body oblong, or ovate, compressed; head short, deep; snout short; eye very large; mouth large, oblique; lower jaw projecting; teeth in jaws in villiform bands, present also on vomer and palatines; posterior nostril large, elongate; preopercle serrate, with 1 or more spines or enlarged serrations at angle; opercle short, with 1 to 3 points or spines; lateral line complete, not extending on caudal fin; scales firm, ctenoid, extending on head, snout and maxillaries, but not on the fins; dorsal fin continuous, with about 10 spines; anal with 3 spines; ventrals thoracic, with I, 5 rays.

Two genera, *Priacanthus* and *Pseudopriacanthus*, occur in American waters, which have not heretofore been recorded from Perú. The last mentioned genus is represented by a fine specimen in the collection from Talara, Perú.

Genus PSEUDOPRIACANTHUS Bleeker, 1869

Body very deep, its depth usually equal to or greater than half its length to the base of caudal; scales moderately large, about 35 to 55 in a lateral series; dorsal with about X, 10 or 11 rays; anal with about III, 10 or 11.

This genus, which occurs in the Atlantic and Pacific, is new to the fauna of Perú.

PSEUDOPRIACANTHUS SERRULA (Gilbert)

Priacanthus serrula GILBERT, 1890, p. 450, Albatross Station 2797, 8°6'30" N., 78°51' W., Panamá Bay, in 33 fathoms (original description).

Pseudopriacanthus serrula JORDAN and EVERMANN, 1896, p. 1239 (description); Meek and Hildebrand, 1925, p. 490 (description).

?*Pseudopriacanthus lucasanus* CLARK, 1936, p. 388, Cape San Lucas, Baja California (original description).

Head 2.6; depth 1.8; D. X, 11; A. III, 10; P. 17; scales 53.

Body short and deep, moderately compressed, the ventral outline anteriorly more strongly convex than the dorsal; caudal peduncle short and deep, 2.8 in head; snout only about half length of eye, 4.35 in head; eye extremely large, 2.25; interorbital 4.3; mouth strongly oblique; lower jaw projecting prominently, entering general dorsal outline of head; maxillary nearly as broad as pupil, not quite reaching vertical from anterior margin of pupil, 1.85 in head; teeth in jaws in villiform bands, some of the outer ones in anterior part of each jaw slightly enlarged, also present in villiform bands on vomer and palatines; preorbital bone scarcely half width of pupil, rather finely serrate above and below; supraorbital ridge finely serrate; preopercle with fine serrae on its vertical margin and with larger ones at its angle and on the horizontal margin; gill rakers fairly short, 17 on lower limb of first arch; lateral line arched anteriorly, running rather close to back; scales small, strongly ctenoid, extending forward on head, covering it fully except for the premaxillaries and the lower lips; dorsal fin long continuous, the spines fluted, graduated to fourth, the fourth to seventh of nearly equal length, the rest shorter, the fifth 1.45 in head, the margin of the soft part convex, the rays spinous at base, the longest ones only a little shorter than the longest spines; caudal fin round, about as long as head without snout; anal with three graduated, fluted spines, the third 2.3 in head, the longest soft rays much longer than the longest spine, about equal to longest rays of dorsal; ventral fin large, reaching opposite base of second anal spine, nearly as long as head, its spine 1.1 in head; pectoral fin shorter, rather broadly rounded, 1.6 in head.

Color uniform light gray, scarcely paler below than above; fins uniform pale except for dark tips or margins of the soft parts of the dorsal and anal, and the caudal and ventral.

The description was based on a single large specimen, 280 mm. in total length, which was taken off Talara, Perú. It was compared with the small type, which is only 38 mm. in total length. The comparison, although not entirely satisfactory, shows fair agreement. The two agree in the number of fin rays present, and perhaps more signifi-

cantly the two agree in the small number of gill rakers present, wherein this species seems to differ from related ones. It is close to *P. altus*, from the West Indies and the Atlantic coast of the United States, apparently differing principally in having 17 gill rakers on the lower limb of the first arch, instead of 20 as in *P. altus*. *P. serrula* also is close to *P. nipponius*, a Japanese species, from which it also differs in having fewer gill rakers, a broader interorbital, and rather longer fin spines. The small specimen, 73 mm. in total length, from Cape San Lucas, Baja California, described by Clark (1936, p. 388) as *P. lucasanus*, probably is the same as *P. serrula*, though a few characters as given are in disagreement. The anal formula, "II, 10," perhaps may be dismissed as a typographical error, as the presence of 3 spines is the normal number for the members of the family. The oversight of teeth on the vomer and palatines, also a family character, presumably led to the assertion that none were present.

Range.—Previously reported only from Panamá Bay. The known range is now extended southward to Talara, Perú, and somewhat doubtfully, northward to Cape San Lucas, Baja California.

Family POMADASIDAE: Grunts

ORTHOPRISTIS CHALCEUS (Günther)

Orthopristis chalceus HILDEBRAND, 1946, p. 284 (description).

A single specimen, 59 mm. in standard length (caudal fin broken), is present in the collection. The species probably is not common in Perú, as the U. S. Fish and Wildlife Service Mission to Perú in 1941 did not obtain any specimens. It has been recorded, however, from two places in Perú, namely, from Lobos de Afuera, and from Callao (Hildebrand, 1946, p. 248).

Range.—Gulf of California to the Galápagos Islands and northern Perú.

Family SCIAENIDAE: Croakers, Drums, etc.

Genus EQUETUS Rafinesque, 1815

Body oblong, compressed; back much elevated anteriorly, descending rapidly posterior to first dorsal fin; mouth small, inferior, lower jaw included; snout with rather prominent pores and slits; preopercle with serrated membranous border; teeth in jaws in villiform bands, some of them occasionally enlarged; gill rakers short and rather few, about 8 to 12 on lower limb of first arch; scales rather small, ctenoid; soft part of dorsal very long, with about 35 to 55 rays; anal small, with only about 5 to 8 soft rays.

This genus was not known from Perú when U. S. National Museum Bulletin 189, 1946, was prepared. However, Mr. Barton obtained a specimen of this genus at Talara, Perú, in 1946, which he described (1947, p. 1) as *Eques*³ *lanfeari*.

EQUETUS LANFEARI (Barton)

FIGURE 5

Eques lanfeari BARTON, 1947, p. 1, fig. 1, Talara, Perú, from a depth of 250 feet. (Description, based on the holotype (A.M.N.H. No. 17081), 290 mm. in total length.)

Head 3.2; depth 2.7; D. XII, 35 or 36; A. II, 7; scales in 80 transverse series above lateral line, 12 rows between lateral line and middle of first dorsal.

Body deep, much compressed; head compressed; snout blunt, not protruding beyond premaxillaries, 3.0 in head; eye 4.7; interorbital 3.7; mouth nearly horizontal; maxillary reaching about under middle of eye, 2.6 in head; tip of lower jaw with a fleshy knob; posterior nostril oval, the anterior one somewhat triangular and smaller; teeth in wide bands in both jaws, the outer ones in upper jaw enlarged; gill rakers very short, 9 exclusive of rudiments on lower limb of first arch; lateral line not distinct, rather strongly arched; scales strongly ctenoid, extending on soft dorsal, caudal, and anal; dorsal fins barely continuous, spinous dorsal short, the first spine very short, the second and third high, the third 1.8 in head; second dorsal very long and rather low; caudal fin rounded; anal small, the second spine enlarged, 2.2 in head; ventral nearly as large as the pectoral, inserted almost under base of pectoral, 1.6 in head; pectoral 1.7 in head.

Color gray, purplish along back, a little lighter on belly; all fins dusky at edges; snout, opercles and preopercles darker; four distinct, horizontal, dark stripes, the first about one-third of the pupil in width, starting below middle of first dorsal and running along base of fin to middle of soft dorsal; the second, about one-half of the pupil in width, starting about the length of snout below the first dorsal spine and curving backward to base of third hindermost ray of soft dorsal; the third slightly wider, from back of opercular angle to upper third of peduncular base; the fourth a little narrower, starting a little behind lower pectoral base and running back to above posterior anal base. (Reorganized and somewhat reworded after Barton.)

³ *Eques* Linnaeus (1758, p. 459) is preoccupied in Lepidoptera, but *Equetus* Rafinesque (1815, p. 86) is available.

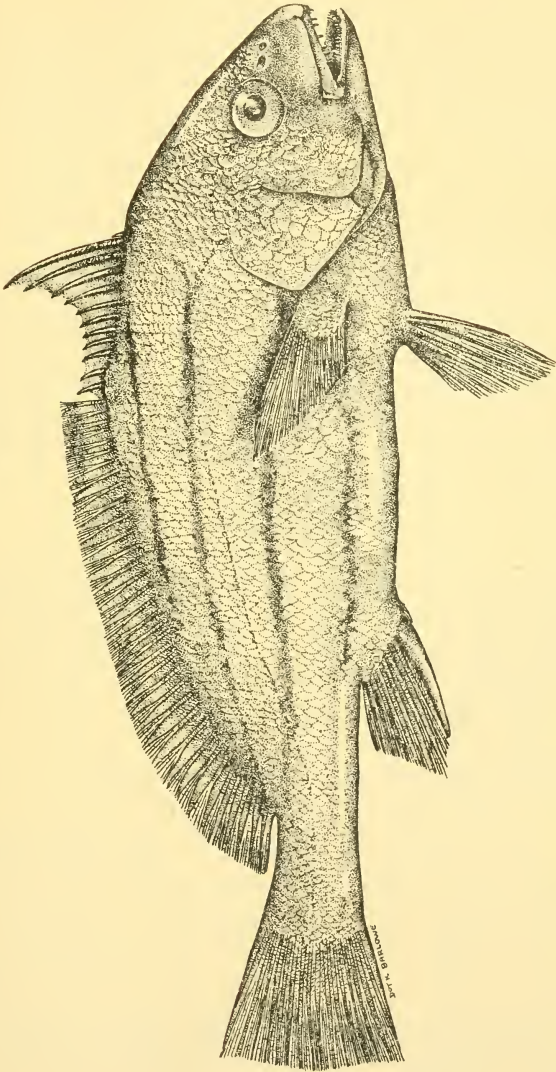


FIG. 5.—*Equetus laufeari* (Barton). From the type, 290 mm. long, Talara, Perú (A.M.N.H. No. 17081). (After Barton, 1947.)

This species probably is nearest *E. acuminatus* (Bloch and Schneider) from the Atlantic, from which it differs prominently in the much smaller scales. From the other two species, *E. viola* (Gilbert) and *E. fuscovittatus* (Kendall and Radcliffe), known from the Pacific coast of America, it differs in color and in the lower spinous dorsal.

Range.—Known only from off Talara, Perú.

Family CHAETODONTIDAE: Butterflyfishes, Angelfishes

Genus *HOLACANTHUS* Lecépède, 1803

Body oblong, rather robust, the depth usually about equal to half the total length; back round; head short, blunt; preopercle serrate along vertical margin, with a large spine at angle, preceded by 1 to 3 spines in lower margin of preopercle; interopercle anteriorly with 1 to 4 short spines; preorbital anteriorly with coarse serrae; scales firm, strongly serrate, fluted, accessory scales generally present; dorsal with about 12 to 15 spines; soft part anteriorly sometimes elevated; anal with three graduated spines, the soft part similar to that of dorsal. Color usually brilliant.

The genus is now reported from Perú for the first time.

HOLACANTHUS PASSER Valenciennes

Holacanthus passer VALENCIENNES, 1855, p. 327, Galápagos Islands (original description; figure published in atlas, 1846, as plate 6); Jordan and Evermann, 1898, p. 1682 (description); Meek and Hildebrand, 1928, p. 778 (description; range).

Holacanthus strigatus GILL, 1862, p. 243, Cape San Lucas, Baja California (original description).

Head 4.0; depth 1.65; D. XIV, 19; A. III, 19; P. 17; scales along middle of side 46.

Body short and deep, well compressed, its ventral profile anteriorly strongly convex, its dorsal profile slightly concave over eyes, steep at nape; caudal peduncle short, strongly compressed, 1.6 in head; head short, deep; snout blunt, 2.6; eye small, 4.5; mouth small, terminal; maxillary under preorbital, reaching about to vertical from anterior nostril, 3.3 in head; teeth in jaws, slender, bristlelike, movable, mostly in 2 series; preopercle with a rather finely serrate vertical margin, at angle, a large spine exceeding diameter of eye, preceded on lower margin by 3 smaller spines; interopercle anteriorly with 2 spines; preorbital anteriorly coarsely serrate; gill rakers short, 12 somewhat developed on lower limb of first arch; lateral line pores undeveloped; scales strongly ctenoid, fluted, mostly with accessory scales at base, extending forward on snout and chin, covering soft parts of the

vertical fins completely, and extending more or less on the rays of the paired fins; dorsal fin very long, its origin a little in advance of margin of opercle, its spines rather short, slightly graduated, the third 2.3 in head, the soft part with a produced lobe about twice as long as head; caudal round, about as long as head; anal with 3 graduated spines, the soft part similar to that of dorsal; ventral fin long, the 2 outer rays filamentous, the longest filament reaching origin of anal, about 3.0 in length, its spine slender, 1.45 in head; pectoral broad, with slightly convex margin, about as long as head.

Color satin-black; a white vertical bar under sixth dorsal spine, about as broad as eye, ending under tips of middle rays of pectoral; caudal, ventrals and pectorals and distal parts of lobes of dorsal and anal pale; the margin of the caudal black.

This species, which is new to the fauna of Perú, is represented in the collection by one fine specimen, 220 mm. in total length.

Range.—Previously known from Acapulco, México, to the Galápagos Islands. Now for the first time reported from Perú from a specimen caught off Talara, Perú.

Family CALLIONYMIDAE: Dragonets

Genus SYNCHIROPUS Gill, 1860

The single small specimen in the collection, which apparently represents a new species, seems to belong to the genus *Synchiropus* Gill, as understood by at least some modern ichthyologists.⁴ This genus seems to be characterized by the broad, smooth body; the absence of a tentacle above the eye; the single lateral line; the superior gill opening, with at least a slight free opercular flap in front of and below it; and by the two well-separated dorsal fins, with the rays in the second fin divided in adult fish.

SYNCHIROPUS TALARAE, new species

FIGURE 6

Head 3.1; depth 9.3; D. IV, 9; A. 8; P. 24; V. 6.

Body strongly depressed, broader than deep except at base of caudal; head large, very strongly depressed, its depth only about half its width, and 3.0 in its length; snout depressed, triangular, much shorter than eye, 4.7 in head; eye definitely more superior than lateral, 3.5; interorbital very narrow, slightly grooved, about 12 in eye;

⁴I am indebted to Dr. Leonard P. Schultz, who has recently examined many specimens of the family Callionymidae from many parts of the world to determine generic and specific relationships, for suggesting that this Peruvian species belongs to the genus *Synchiropus*. (S.F.H.) (See Schultz and Woods, Journ. Washington Acad. Sci., vol. 38, No. 12, pp. 419-420, 1948.)

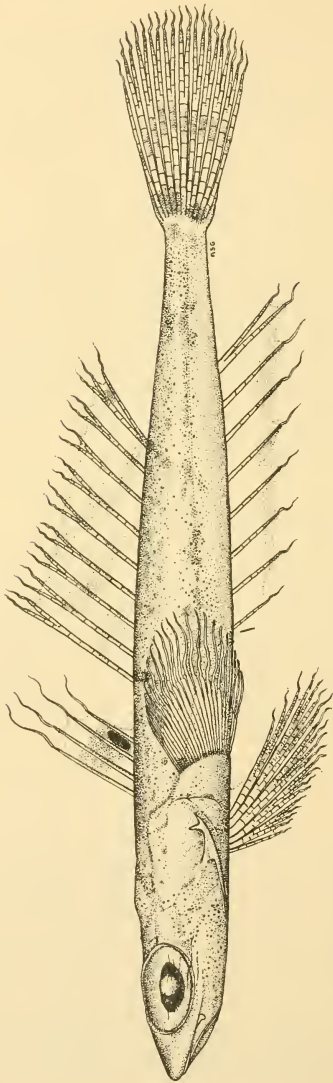


FIG. 6.—*Synchiropus talarae*, new species. From the type, 35 mm. long, Talara, Perú (U.S.N.M. No. 144258).

mouth rather large, lower jaw shorter than upper, included; maxillary reaching nearly to anterior margin of pupil, 3.75 in head; teeth in jaws minute, apparently in a narrow band; preopercular spine strong, curved upward posteriorly, bifurcate distally, the upper spine the stronger, directed upward; gill opening superior, being an elongate transverse slit; lateral line single; first dorsal with four slender spines, each bearing a short filament, none reaching second dorsal without filament, origin of fin over the space between gill opening and base of pectoral, distance from snout 3.1 in standard length; second dorsal well separated from the first, the anterior rays a little higher than the posterior ones, each with a short filament and all falling far short of reaching base of caudal with filaments included; caudal fin apparently somewhat rounded about equal to distance from tip of snout to base of preopercular spine; anal with widely separated rays, increasing gradually in length, but not reaching base of caudal, each ray with a short filament, origin of fin a little nearer base of caudal than tip of snout, its distance from tip of snout 1.8 in standard length; ventral rather large, inferior, the rays slightly filamentous distally, longest filament scarcely reaching opposite vent, inserted nearly equidistant from tip of snout and vent, 1.3 in head; pectoral inserted about over midlength of ventral, the rays filamentous distally, reaching slightly beyond origin of anal, 1.8 in head.

General color brownish above, pale underneath; back with a dark cross line at base of first ray of second dorsal and another one at base of its last ray; side with indefinite dark spots and punctulations; first dorsal with a black spot at base of last ray; rays of second dorsal with an elongate dusky spot somewhat above midlength; caudal fin with a dark bar on its base, its midsection and its margin slightly darker than rest of fin; each anal ray, exclusive of the first two, distally dusky, the filaments pale; ventral pale, with a few dusky dots along the rays; pectoral with a dusky spot at base of upper rays, fin otherwise plain translucent.

This apparently new species is represented in the collection by a single specimen, the holotype (U.S.N.M. No. 144258), 35 mm. in total and 28 mm. in standard length, which is in good condition except that the abdomen has been excavated. *S. talarae* is the third species of this genus to be described from the Pacific coast of America. The other species are *S. atrilabiatum* (Garman) (1899, p. 122), described from specimens dredged by the *Albatross* off Colombia in 112 fathoms and in Panamá Bay in 127 fathoms; and *S. garthi* (Seale) (1940, p. 36, pl. 3), described from a specimen taken at Port Utria, northern Colombia, by one of the Allan Hancock expeditions. The first-mentioned species is well described, but the size of the specimens upon

which it is based is not stated and no figure is offered. The species mentioned last is rather inadequately described, but it was figured. The length of the single specimen upon which the description and figure were based was given as 30 mm. The differences among the three species as determined from descriptions and in part from the figure of *S. garthi* are set forth in the parallel comparison offered. *S. talaræ* seems to be unique in the very low broad head.

<i>atriliabatus</i>	<i>garthi</i>	<i>talaræ</i> , new species
Dorsal rays IV-9.	Dorsal rays IV-8 (according to figure).	Dorsal rays IV-9.
Pectoral rays 23.	Pectoral rays 15 (according to figure).	Pectoral rays 24.
Depth of body ? in head.	Depth of body 2.0 in head.	Depth of body 3.0 in head.
Depth of head two-thirds its width; its width scarcely two-thirds its length.	Depth of head ? in its width; its width ? of its length.	Depth of head one-half its width; its width a little less than half its length.
Length anterior to vent less than half the length to base of caudal.	Length anterior to vent about one-half total length (according to figure).	Length anterior to vent a little more than half the length to base of caudal.
Snout as long as eye.	Snout one-half "width of eye."	Snout about three-fourths length of eye.
Eye "less than one-third of length of head."	Eye 2.5 in head.	Eye 3.5 in head.
Gill opening ?	Gill opening round.	Gill opening elongate.
Posterior rays of dorsal and anal reaching base of caudal.	Posterior rays of dorsal and anal not nearly reaching base of caudal (according to figure).	Posterior rays of dorsal and anal not nearly reaching base of caudal.
Anal and ventral rays with filaments ("fringed").	None of fin rays with filaments (according to figure).	Nearly all rays of fins with short filaments.
Upper part of body with numerous closely placed brown cross streaks; first dorsal with a dark spot on outer half between the third and fourth rays.	Body without cross streaks, but with many brown specks; first dorsal dusky at base, but without a black spot.	Body with a very narrow brownish cross streak at base of first ray of second dorsal and another at base of its last ray, and with indefinite dark spots and punctulations; first dorsal with a large black spot.

Family BROTLIDAE: Brotulid eels

BROTULA ORDWAYI, new species

FIGURE 7

Head 4.25; depth 4.4; D. 110; A. 85; P. 23; scales about 225 (too small and irregular to enumerate accurately).

Body moderately elongate, rather strongly compressed throughout, its thickness at tips of pectoral fins only about half its depth at same place; head compressed, rather narrow and definitely convex above, its depth at margin of preopercle 6.0 and its width at same place 9.1 in standard length; snout a little longer than eye, 4.1 in head; eye elongate, 5.4; interorbital narrow, convex, 8.0 in head; mouth moderate, slightly oblique; lower jaw notably shorter than the upper, included; maxillary broad, reaching vertical from posterior rim of orbit, 2.25 in head; anterior pair of barbels of snout larger than the lateral pair and of about the same length as the nasal barbels, 2 prominent flaps of skin between the anterior and lateral barbels, the 6 mandibular barbels all of about equal length; a pair of pores between the anterior barbels, and 1 between the anterior and the lateral barbels; lips rather thick, rugose; teeth small, pointed, in bands on jaws, vomer, and palatines, the band on vomer broadly triangular, approaching a U-shape; 3 gill rakers and 10 rudiments on lower limb, and 4 rudiments on upper limb of first arch; lateral line running high, broadly arched anteriorly, nearly complete; scales small, strongly striate, extending forward on the snout, and on the fins, about 30 oblique rows between posterior rim of orbit and base of opercular spine; dorsal fin long and low, its origin about half an eye's diameter in advance of base of pectoral, its distance from tip of snout 4.0 in standard length, the longest rays about as long as snout and half the eye; caudal fin rounded, fully united with the dorsal and anal, only a little longer than snout; anal similar to the dorsal, its origin well in advance of midlength without caudal fin, its distance from tip of mandible 2.4 in standard length; ventrals short, the longest filament 3.1 in head; pectoral fin broadly rounded, scarcely reaching halfway to origin of anal, 2.0 in head, 8.7 in standard length.

Color very dark brown; sides and upper surface of head and body, to or a little beyond vertical from origin of anal, with many round black spots, the largest ones nearly as big as pupil; ventral fins dusky; other fins very dark brown, nearly black, with a very narrow pale margin.

The foregoing description is based on the holotype (U.S.N.M. No. 144259) and only specimen known, which is 375 mm. in total and 347 mm. in standard length. It differs rather prominently from the

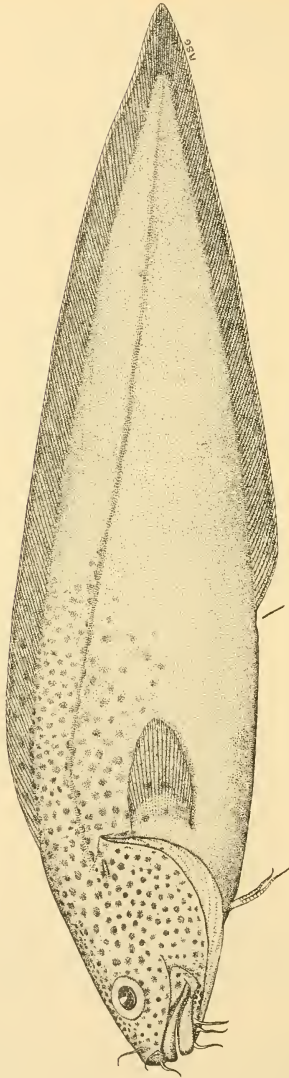


FIG. 7.—*Brotula ordwayi*, new species. From the type, 375 mm. long, Talara, Perú (U.S.N.M. No. 144359).

other American species recognized by Hubbs in his revision (1944, pp. 162-178), as shown in the parallel comparison that follows.

The species was named for Samuel Ordway, the judicious trustee of the New York Zoological Society.

<i> barbata</i>	<i> clarkae</i>	<i> ordwayi</i> , new species
Body quite elongate, its depth 5.5 to 6.0 in standard length.	Body quite elongate, its depth 5.9 in standard length.	Body deeper, its depth 4.4 in standard length.
Head low, somewhat flattened above, its depth at margin of preopercle 6.6 to 6.9 in standard length.	Head low, somewhat flattened above, its depth at margin of preopercle 6.7 in standard length.	Head more convex above, its depth at margin of preopercle 6.0 in standard length.
Mouth large, the maxillary reaching well beyond posterior rim of orbit, 2.0 to 2.1 in head; jaws of about equal length.	Mouth large, the maxillary reaching rather far beyond eye, 2.0 in head; lower jaw slightly longer than the upper.	Mouth smaller, the maxillary reaching under posterior rim of orbit, 2.25 in head; lower jaw notably shorter than upper, included.
Vomerine teeth in a triangular patch, each arm of triangle with a constriction, nearly but not quite pinching off a posterior patch.	Vomerine teeth roughly in a triangular patch, rounded at apex, arms of triangle without a constriction.	Vomerine teeth in a broad triangular patch, approaching the shape of a U, the arms without a constriction.
Origin of dorsal behind base of pectoral, its distance from tip of snout 3.6 to 3.8 in standard length.	Origin of dorsal behind base of pectoral, its distance from tip of snout 3.6 in standard length.	Origin of dorsal definitely in advance of base of pectoral, its distance from tip of snout 4.0 in standard length.
Origin of anal at midlength without caudal fin, its distance from tip of lower jaw 1.9 in standard length.	Origin of anal a little in advance of midlength without caudal fin, its distance from tip of lower jaw 2.1 in standard length.	Origin of anal rather far in advance of midlength without caudal fin, its distance from tip of lower jaw 2.4 in standard length.
Ventral fins rather long, the longest filament reaching a little beyond base of pectoral, 1.8 to 2.2 in head.	Ventral fins long, reaching about an eye's diameter beyond base of pectoral, 2.1 in head.	Ventral fins short, the longest filament scarcely reaching base of pectoral, 3.1 in head.
Pectoral fin reaching much less than halfway to origin of anal, 8.4 to 8.8 in standard length, with 24 or 25 rays.	Pectoral fin reaching about halfway to origin of anal, 8.3 in standard length, with 27 rays.	Pectoral fin scarcely reaching halfway to origin of anal, 8.7 in standard length, with 23 rays.

<i> barbata</i>	<i> clarkae</i>	<i> ordwayi</i> , new species
Scales moderately small, about 210 in a lateral series, about 32 between posterior rim of orbit and base of opercular spine.	Scales very small, about 220 in a lateral series, about 45 between posterior rim of orbit and base of opercular spine.	Scales very small, about 225 in a lateral series, about 30 between posterior rim of orbit and base of opercular spine.
Head and body (at least in adults) plain, without round black spots; the dorsal and anal fins more or less pale at base, with dark margins.	Head and body (at least in adults) plain, without round black spots; the dorsal and anal pale at base, with dark margins.	Head and anterior part of body profusely spotted with black; the dorsal and anal black, with narrow pale margins.

Family OPHIDIIDAE: Cusk eels

Genus LEPOPHIDIUM Gill, 1895

Body quite elongate, compressed, tapering regularly and rather gradually to more or less of a point posteriorly; head low, somewhat compressed; snout with or without a spine (present in all Pacific coast species); mouth rather large and broad, nearly horizontal; teeth in jaws in villiform bands, the outer ones in each jaw more or less enlarged, rather shorter and blunter on vomer and palatines; gill rakers short and few; lateral line present at least anteriorly; scales very small, with many radiating striae, extending forward on head to or beyond interorbital region; dorsal and anal fins continuous with the caudal fin.

Occurring in rather deep water on both coasts of America. About nine species have been recognized. Now reported from Perú for the first time.

LEPOPHIDIUM NEGROPINNA, new species

FIGURE 8

Head 4.6; depth 7.5; D. 128;⁵ A. 114;⁵ P. 23;⁵ scales 220.⁵

Body moderately slender, compressed, its greatest thickness about two-thirds its depth; head long, low, a little deeper than broad over margin of preopercle; snout blunt, 4.8 in head, with a strong spine extending beyond premaxillaries; eye moderate, 5.0 in head; interorbital 5.0; mouth large, nearly horizontal; lower jaw shorter than

⁵ The enumerations are only approximately correct because the fin rays are enveloped in rather thick skin and are not all visible, and the scales are too small and the series too irregular to count accurately.

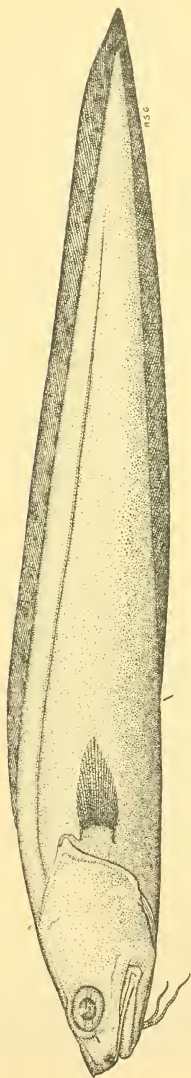


FIG. 8.—*Lepophidium negropinna*, new species. From the type, 280 mm. long, Talara, Perú (U.S.N.M. No. 144256).

	<i>provarus</i>	<i>microlepis</i>	<i>pardale</i>	<i>stigmatismum</i>	<i>emmelas</i>	<i>negropinus</i> , new species
Dorsal rays	127.*	120.*	117.*	117.*	102.*	128.*
Anal rays	106.*	103.*	100.*	103.*	80.*	114.*
Scales in lateral series	212, between nape and origin of dorsal 30.*	248, between nape and origin of dorsal 45.*	228, between nape and origin of dorsal 28.*	210, between nape and origin of dorsal 36.*	Scales in lateral series 225, between nape and origin of dorsal 49.*	Scales in lateral series 225, between nape and origin of dorsal 36.*
Gill rakers	3 + 9, 4 developed.	4 + 9, 4 developed.	3 + 6, 4 developed.	4 + 13, 7 developed.	4 + 16, 9 developed.	3 + 14, 5 developed.
Body moderately slender, its depth	7.8 in standard length.	7.1 in standard length.	8.4 in standard length.	8.2 in standard length.	deep, its depth 5.9 in standard length.	moderately slender, its depth 7.5 in standard length.
Rostral spine	not prominent, scarcely reaching beyond margin of premaxillaries.	spine fairly prominent, reaching margin of premaxillaries.	spine prominent, reaching margin of premaxillaries.	spine rather prominent, reaching well beyond margin of premaxillaries.	spine short, failing notably to reach margin of premaxillaries.	spine very prominent, extending far beyond margin of premaxillaries.
Origin of dorsal	in advance of midlength of pectoral.	in advance of midlength of pectoral.	in advance of midlength of pectoral.	dorsal over midlength of pectoral.	dorsal over base of pectoral.	littoral.
Pectoral reaching	rather less than halfway to origin of anal, 10.5 in standard length.	reaching less than halfway to origin of anal, 8.3 in standard length.	reaching less than halfway to origin of anal, 11.0 in standard length.	scarcely reaching halfway to origin of anal, 11.0 in standard length.	long, failing to reach origin of anal by diameter of pupil, 7.5 in standard length.	reaching notably more than halfway to origin of anal, 10.7 in standard length.
Inside of gill covers	pale.	of gill covers pale.	of gill covers pale.	of gill covers dark brown.	of gill covers dark brown.	of gill covers pale.
Dorsal and anal	with dark margins.	with dark blotches on margin, anal with continuous dark margin.	with dark blotches near beginning, anal with a continuous dark margin.	with a dark blotch near beginning, anal with a continuous dark margin.	and anal dusky, without dark margins.	with dark margin and dark blotches along base, anal uniform black.
Peritoneum	pale.	pale.	pale.	pale.	dark brown.	pale.

* These enumerations are not accurate because the fin rays are enveloped in rather thick skin and are not all visible, and the scales are too small and irregularly arranged to count unerringly.

the upper, included; maxillary reaching well beyond posterior margin of eye, 2.1 in head; teeth in jaws in villiform bands, the outer ones in both jaws enlarged, those on vomer and palatines stronger, short and blunt; opercle with a concealed point; gill rakers 14 on lower limb, 5 somewhat developed, and 3 tubercles on upper limb; lateral line running rather high anteriorly, disappearing posteriorly; scales very small, rather difficult to enumerate accurately, extending forward on head to snout, 36 rows crossing back between nape and origin of dorsal; dorsal fin very long and low, the rays rather difficult to enumerate because of heavy skin, the origin of fin a very short distance behind base of pectoral, its distance from tip of snout 4.0 in standard length; caudal fin scarcely as long as eye, slightly rounded, fully continuous with dorsal and anal; anal fin similar to dorsal, its origin behind that of dorsal a distance about equal to postorbital length of head; the outer (or posterior) filament of ventral fin much the longer, 2.9 in head; pectoral rather long, reaching notably more than halfway to origin of anal, 10.7 in standard length and 2.3 in head.

Color uniform dark brown, scarcely paler below than above; inside of gill covers pale; outer edge of dorsal fin black, base lighter with dark spots; caudal and anal fins blackish; ventral filaments pale; pectoral a little darker than the general color of the body, with numerous dark punctulations visible under magnification; these punctulations present on the lower parts of the head and body.

This apparently new *Lepophidium* is represented by a single specimen (U.S.N.M. No. 144256), 280 mm. in total and 269 mm. in standard length. To identify this fish it was compared with the holotypes of all the species of the genus reported from off the Pacific coast of America. Its relationship with the other species, as indicated by the holotypes, is shown in the parallel comparison offered herewith. The numerous dorsal rays, the very small scales, the rather high number of gill rakers, the very prominent rostral spine, the anterior origin of the dorsal, the uniform dark brown body, and the black vertical fins characterize this species.

The name, *negropinna*, was suggested by the black vertical fins.

Genus OTOPHIDIUM Gill, 1885

Body elongate, considerably compressed; head compressed; snout without a spine; opercle with a strong spine; scales not in regular series and not imbricated (except in *indefatigable*, in which they are in fairly regular series and more or less imbricated), but partly or mostly at right angles to each other; dorsal and anal fins fully continuous with the caudal.

This genus is said to differ from *Ophidion* in having a short thick air bladder with a large foramen. However, several species have not been examined for this character.

OTOPHIDIUM FULVUM, new species

FIGURE 9

Head 5.6; depth 8.6; D. about 115; A. about 83; P. 26 or 27.

Body elongate, definitely compressed, its greatest thickness about two-thirds its depth; head rather deep, compressed; snout somewhat pointed, no rostral spine, extending beyond premaxillaries, 5.7 in head; eye slightly elongate, 3.4; interorbital very narrow, 12; mouth large, nearly horizontal; lower jaw shorter than the upper, included; maxillary extending well beyond posterior margin of pupil, 2.4 in head; teeth in jaws in villiform bands, the outer ones in each jaw somewhat enlarged, those on vomer and palatines strong, low, and bluntly pointed; opercle with a strong spine; gill rakers consisting of spiny tubercles, 4 on the lower limb (2 somewhat developed), and 2 on the upper one; lateral line rather high, absent posteriorly; scales not in regular series, more or less embedded, elongate, many at right angles to each other; dorsal very long and low, the rays difficult to enumerate, origin of fin well behind midlength of pectoral, its distance from tip of snout 4.2 in standard length; caudal fin very short, continuous with the dorsal and anal; anal fin similar to the dorsal, though shorter, its origin about length of head behind that of dorsal, and its distance from tip of mandible 2.8 in standard length; ventral inserted at vertical from middle of eye, the outer filament the longer, 2.0 in head; pectoral fin short and broad, with rounded margin, with many rays,⁶ reaching notably less than halfway to origin of anal, 11.6 in standard length, 2.05 in head.

Color uniform brown, though somewhat lighter on chest and abdomen than elsewhere; many dark punctulations visible on the body under magnification; dorsal and anal fins with narrow dark margins, extending around the tail.

This apparently new species is represented by a single specimen (U.S.N.M. No. 144257) 72 mm. in total and 69 mm. in standard length. It seems to be nearest *O. galeoides* Gilbert, known from the Gulf of California, the type of which is at hand. From that species it differs, however, in several characters, as shown in the parallel comparison offered herewith. From *indefatigable* Jordan and Boll-

⁶ To obtain an accurate enumeration of the rays the skin was cut behind the fin and near the base.

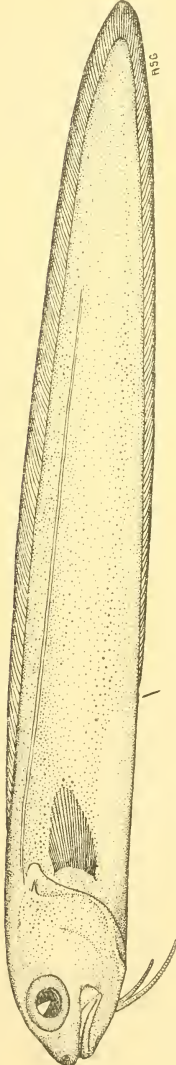


FIG. 9.—*Otophidium fulvum*, new species. From the type, 72 mm. long, Talara, Perú (U.S.N.M. No. 144257).

man, which is known from Panamá Bay to the Galápagos Islands, it differs prominently in the arrangement of the scales, which are in irregular series and at right angles to each other in *fulvum*, while they are nearly all in regular series and more or less imbricated in *indefatigable*. It differs prominently from *O. scrippsi* Hubbs in the fewer, shorter, spiny gill rakers, and slenderer body.

The specific name *fulvum* is in allusion to the brown color of the specimen described.

galeoides

Pectoral fin moderate, reaching notably more than halfway to origin of anal, 7.25 in standard length, and 1.35 in head, with 21 rays.

Gill rakers strong, 4 on lower limb all fairly well developed, and 2 tubercles on upper limb of first arch.

Maxillary reaching posterior margin of pupil, 2.15 in head.

Origin of dorsal over midlength of pectoral, its distance from tip of snout 3.75 in standard length.

fulvum, new species

Pectoral fin shorter, reaching notably less than halfway to origin of anal, 11.6 in standard length, and 2.05 in head, with 26 or 27 rays.

Gill rakers all spiny tubercles, none well developed, 4 on lower limb and 2 on the upper one of first arch.

Maxillary reaching a little beyond posterior margin of pupil, 2.4 in head.

Origin of dorsal well behind midlength of pectoral, its distance from tip of snout 4.2 in standard length.

Family MUGILIDAE: Mulletts

MUGIL CEPHALUS Linnaeus

Mugil cephalus HILDEBRAND, 1946, p. 422 (description).

Two small specimens, 30 and 43 mm. in total and 24 and 33 mm. in standard length, are included in the collections. The juvenile anal fin formula, II, 9, has been retained in these specimens. *M. cephalus* seems to be a common species in northern Perú. Numerous specimens of young and a few adults were included in the collections made by the U. S. Fish and Wildlife Service mission to Perú in 1941 (Hildebrand, 1946, p. 422).

Range.—Shores of nearly all warm seas; on the Pacific coast of America from California to Chile.

MUGIL CUREMA Cuvier and Valenciennes

Mugil curema HILDEBRAND, 1946, p. 426 (description).

One small specimen 45 mm. in total and 37 mm. in standard length is included in the collection. This specimen still has the juvenile anal

fin formula, II, 10, the third ray having not yet developed into a spine. Only a few young and no adults were included in the collections made by the U. S. Fish and Wildlife Service mission to Perú in 1941 (Hildebrand, 1946, p. 426).

Range.—Known from both coasts of America; on the Pacific coast from the Gulf of California to Chile.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS

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Thomas Lincoln Casey Fund

LARVAE OF THE ELATERID BEETLES
OF THE TRIBE LEPTUROIDINI
(COLEOPTERA: ELATERIDAE)

BY

ROBERT GLEN

Research Coordinator, Division of Entomology, Science Service, Department of Agriculture,
Ottawa, Canada



(PUBLICATION 3987)

CITY OF WASHINGTON
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LARVAE OF THE ELATERID BEETLES
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INTRODUCTION

Characters for the identification of species are sadly lacking for most of the larval Elateridae. This lack of fundamental information is not surprising because most elaterid larvae are difficult to find and they require several years to mature. The task of collecting and rearing them is so great that only a small proportion of the species is known in the larval stage, and progress in larval taxonomy has been handicapped constantly by insufficient representation to characterize the genera. This is particularly true of the Lepturoidini, which includes important crop pests throughout the world, especially in western North America. Many of these pest species are now known to react differentially to factors of weather, soil, and culture, and the control program to be prescribed depends largely upon the species involved. Thus, accurate specific identification is the first need of the economic investigator.

It was largely to fill such a need that the present study arose. In 1922 K. M. King, Officer in Charge of the Dominion Entomological Laboratory, Saskatoon, Saskatchewan, initiated investigations upon wireworm control in the Prairie Provinces, and as an integral part of the project he included studies of larval morphology. He continued this work, as time permitted, until 1929 and succeeded in rearing several of the pest species and in obtaining characters for the separation of their larvae in the field. The author was then made responsible for the furtherance of this work, and in 1931 he prepared descriptions of the larvae of 18 Saskatchewan species. This experi-

¹ Formerly in charge Wireworm Investigations, Dominion Entomological Laboratory, Saskatoon, Saskatchewan.

ence, together with a study of the literature, convinced the writer that adequate generic and specific characters could not be drawn from an investigation limited to the Elateridae of Saskatchewan, or from superficial studies covering a larger region. Instead, he concluded that true generic and specific characters could be obtained only through an intensive comparative study involving all available species of the group under investigation.

The present study, which deals particularly with the genus *Ludius* Eschscholtz, is based upon these principles. In the broad sense it consists of two parts: a detailed treatment of all available identified *Ludius* larvae in the world, and a comprehensive survey of the larval morphology of the other genera included by Hyslop (1917) in the tribe Lepturoidini. The investigation was discontinued in 1942 and is believed to be a reasonably complete record and analysis of the pertinent information available at that time. Only mature or nearly mature larvae are considered. The 93 species included represent 11 genera as follows: *Athous* (14), *Crepidomenus* (1), *Cryptohypnus* (5), *Eamus* (2), *Elathous* (1), *Hemicrepidius* (5), *Hypnoidus* (3), *Lepturoides* (3), *Limonius* (14), *Ludius* (44), and *Melanactes* (1). It is essentially a study in detail and will be used most conveniently by workers who have a knowledge of the basic morphology of elaterid larvae as outlined by Glen, King, and Arnason (1943).

ACKNOWLEDGMENTS

By far the greater part of this study was conducted at the Dominion Entomological Laboratory, Saskatoon, Saskatchewan. However, more than 6 months' intensive research was done in 1936-37 at the United States National Museum, Washington, D. C., and considerable time was devoted to this project at the University of Minnesota, Minneapolis, Minn., where the writer was privileged to work under a Caleb Dorr Fellowship for 1931-32 and a Shevlin Fellowship for 1932-33.

With deep appreciation the writer acknowledges his indebtedness to these institutions and to the many friends and associates who have given stimulating and helpful advice throughout the study. Special acknowledgment of assistance is due Dr. Kenneth M. King, formerly in charge of the Saskatoon laboratory, who contributed so much to the viewpoint, the plan, and the methods adopted, and with whom constant consultation has been a valuable privilege; Dr. A. G. Böving, formerly senior entomologist, United States Bureau of Entomology and Plant Quarantine, Washington, D. C., whose counsel and guidance have been of lasting benefit; Dr. C. E. Mickel, Professor of

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All illustrations were prepared by the writer.

LITERATURE

The first important contribution to the morphology and biology of the larval Elateridae appeared in the last half of the nineteenth century when European workers took an evident interest in larval Coleoptera in general. Chapuis and Candeze (1855), Schiodte (1870), Perris (1863, 1877), Rupertsberger (1880, 1894), and Rey (1887) produced general works that included significant sections on the Elateridae. These paved the way for the comprehensive treatises of Beling (1883-1884) and Henriksen (1911), which were devoted entirely to elaterid larvae. With the advent of World War I, 1914-1918, and the consequent increased attention to agricultural production, there was a marked awakening of interest in the pest species. The identification of closely related forms was required, and broad generic studies gave way to detailed morphology. The results are revealed in the useful papers of Ford (1917), Roberts (1919, 1921, 1922, 1928), Horst (1922), Saalas (1923a, 1923b), Rambousek (1928), Guéniat (1934), Subklew (1934b), and the Australian worker McDougall (1934). An increased interest in biology brought forth the publications of Rambousek (1929) and the German writers Blunck (1925), Langenbuch (1932), and Subklew (1934b). Numerous Russian workers today are contributing valuable biological information in the reports of their faunal surveys and other ecological work.

In America the first important comparative morphology of wireworms originated in investigations of an economic character. The pioneers—Fitch (1867), Comstock and Slingerland (1891), and Forbes (1892)—limited their studies to pest species. Thereafter, interest centered upon control until Hyslop (1917) turned his attention to a study of the larval characters for the identification of the major subdivisions of the family. This work was slightly revised by Böving and Craighead (1931) in their general treatise on coleopterous larvae. The most recent work on comparative morphology has been done in Canada, where Glen (1931, unpublished thesis) distinguished the larvae of 18 species occurring in Saskatchewan, and later Glen, King, and Arnason (1943) worked out the identification of wireworms of economic importance in Canada. As in Europe, however, most of the recent studies have centered on detailed morphology as a basis for the identification of closely related species: Hyslop (1915b), Arnason (1931, unpublished thesis), Hyslop and Böving (1935), Glen (1935, 1941), Hawkins (1936), Jewett (1939), and Lanchester (1939, 1941). Economic entomologists have continued to contribute notes on the biology and ecology of the wire-

worm pests. The most important recent papers concerning species of the tribe Lepturoidini are those of Graf (1914), Hyslop (1915a), Lane (1925, 1931, 1935), King (1928), King, Arnason, and Glen (1933), Strickland (1935, 1939), Stone (1941), and Glen, King, and Arnason (1943).

The first century of work has merely introduced this field of research. Fine progress has been made toward the establishment of characters for subfamilies and for most of the tribes within them. In general, genera and species are poorly defined. This is true particularly of the tribe Lepturoidini, which has been incompletely studied in Europe and almost totally neglected in America. Most of the comparative morphology has been too superficial or too limited in scope to reveal the basic relationships. As a result, all available larval keys to genera and to species have little more than local value; they do not adequately define the genera and species that they include. However, a basis for better comparative work is resulting from the excellent detailed morphological studies of recent years, and more adequate characterization of genera and species should be possible in the near future.

The outstanding taxonomic studies are those of Schiodte, Beling, Henriksen, and Hyslop, while the best work on morphology has been done by Roberts, Hyslop and Böving, and Lanchester. These contributions are discussed separately along with important contemporary works.

SCHIODTE, J. C., 1870: As a pioneer effort this is a most remarkable contribution and must be ranked among the classics of science. Broad, comparative, detailed studies are illustrated with well-selected figures, and conclusions are presented in a systematic conspectus. In some of his descriptions (e.g., *Alaus myops* (Fabricius), p. 500) and in certain figures the author achieves great excellence. However, many descriptions lack important details, and several figures overemphasize sculpture to a disturbing degree. In the systematic conspectus we find the first attempt to provide separating characters for genera and for related species. While this conspectus does not meet our needs today it served as a basis for progress and parts of it are fundamentally sound. The descriptions include 14 species of the tribe Lepturoidini, of which 6 are *Ludius*, but the genera of this tribe are not characterized. Horst (1922, p. 21) criticizes Schiodte, and with some justification, for not stipulating clearly the reliability of the identification of the material used.

PERRIS, EDOUARD, 1877: Very good larval descriptions are found in this work, but most of the illustrations are so small and sketchy

as to be practically worthless. Diagnostic specific characters are stressed, but only two species of *Ludius* are described. There is a key to genera, including several subgenera of *Ludius*, based largely upon the findings of Schiodte.

BELING, TH., 1883-1884: This author discusses 55 European species, 11 belonging to the genus *Ludius*, and a key to species is included. Larval and pupal descriptions are combined with excellent notes on habitat and on the occurrence and duration of the pupal period. On the whole, the descriptions are good and somewhat more detailed than those of Schiodte, but unfortunately no illustrations are given.

COMSTOCK, J. H., and SLINGERLAND, M. V., 1891: This bulletin includes illustrated descriptions of the larvae of five pest species belonging to five distinct genera, along with important notes on their life history. Although it is a pioneer American work the descriptions and figures are done with surprising detail, but many of the figures are smaller than desirable. It has served as a useful model in the progress of this work in America. The descriptions of the two lepturoidine larvae that are included—*Hemicrepidius hemipodus* (Say) (= *Asaphes decoloratus* Say) and *Cryptohypnus abbreviatus* (Say)—are as good as any descriptions yet made of these species, although certain important details are omitted.

FORBES, S. A., 1892: Nine pest species are included in this early American work, but the larvae of only six species are described and illustrated. No *Ludius* larvae are included. Only two of the descriptions are original, the others being taken verbatim from Comstock and Slingerland (1891). Both the descriptions and the figures are useful, although pertinent details are lacking. Of prime significance is the key to genera, which was the only key to elaterid larvae in the American literature until the recent publications of Van Zwaluwenburg (1939) and Glen, King, and Arnason (1943). Ten genera occurring in Illinois are separated, but the lepturoidine genera—*Athous*, *Ludius* (= *Corymbites*), *Hemicrepidius* (= *Asaphes*), and *Cryptohypnus*—are not distinguished. Important observations on bionomics are included.

HENRIKSEN, K. L., 1911: Henriksen extended the work of his fellow countryman J. C. Schiodte. Although his studies are limited to the Danish Elateridae, he describes and illustrates 42 species. His conclusions are presented in several keys. His key to 18 genera separates, for the first time, *Ludius* (= *Corymbites*), *Lepturoides* (= *Campylus*), and *Athous*. Although the characters used do not hold for the larvae of these genera, as recognized throughout the

world, they mark the first step toward this goal. Of the species described, 17 belong to the tribe Lepturoidini. Keys are given to 7 species of *Ludius*, to 5 species of *Athous*, and to 10 species of *Elater* (tribe Elaterini). Unique features of this work are an excellent description of the general morphology of an elaterid larva and a synoptic table summarizing, for each species studied, the "form of the body," "color and sculpture," "length," "nasale," "muscular impressions of the abdominal segments," "ninth abdominal segment," and "other remarks." These characters form the basis of Henriksen's descriptions, and many other characters are quite overlooked, some of which would have assisted in the separation of closely related species. The illustrations are good for gross structure but are not at all reliable for such details as setal characters. However, these are but minor defects in an outstanding work.

XAMBEU, LE CAPITAIN, 1912-1914: Xambeu has brought together his observations on the elaterid larvae, which he published piecemeal over a period of some 20 years. He describes the larvae of 76 species, 32 belonging to the tribe Lepturoidini and 15 to the genus *Ludius*. In making this inclusive study he has drawn freely from the writings of Beling, Perris, Schiodte, and Rey. His descriptions of the larvae of *Ludius melancholicus* (Olivier) and *Ludius amplicollis* (Germar) are original contributions, and these species apparently have not been redescribed by subsequent writers. Unfortunately, most of his descriptions are too general to provide specific distinction, and he gives no keys or figures. The chief merits of the work are the large number of species included and the addition of pertinent new observations on biology, especially on the food of the larvae.

HYSLOP, J. A., 1917: The object of this study was the characterizing of the major subdivisions of the family. Supporting his conclusions by both adult and larval studies, Hyslop improved upon the pioneer work of Schiodte and Henriksen and established a reliable basis for progress in this field of research. His 3 subfamilies (exclusive of the Physodactilinae) are subdivided into 10 well-defined tribes and several other tribes that are included provisionally for forms not represented in the larval material examined. The relative ordinal value of the characters used seems to have been gauged wisely, considering the material available. The study included an examination of larval exuviae of reared specimens representing 33 genera. Characters of 5 other genera were taken from the literature. Excellent figures illuminate the brief tribal descriptions. Genera are not distinguished, and no keys are given. The paleontological record is reviewed, and the phylogeny of the family is discussed.

ROBERTS, A. W. R., 1919-1928: In these four papers Roberts describes representatives of *Agriotus*, *Athous*, and *Ludius* (= *Corymbites*). All are useful descriptions. However, his principal contribution is the excellent detailed morphological study of the larva of *Agriotus obscurus* (Linnaeus) (1921). This is a well-illustrated, careful study, the head, mouthparts, and spiracles being especially carefully done. It has been a most useful guide to ambitious modern investigators. In his 1922 paper Roberts includes a key to genera of Elateridae occurring in Great Britain. This he adapted from Henriksen and it contains little that is new.

HORST, ALBERT, 1922: Realizing the importance of detailed morphology, this author has undertaken to supply omissions in Beling's descriptions of the larvae of *Elater sanguineus* Linnaeus, *Ludius aeneus* (Linnaeus), and *Lacon murinus* (Linnaeus), and to describe fully *Agriotus obscurus* (Linnaeus). The work is rather carefully done, but without closely related species for comparison the author has described in much detail structures that are of no specific value and he has overlooked some of the more pertinent details. Good-sized figures illustrate the gross morphology of the species examined, but important details are lacking. There are no keys. Useful notes on biology are included in the lengthy section on this subject.

HYSLÖP, J. A., and BÖVING, A. G., 1935: This is an excellent contribution to the morphological literature. Detailed observations are recorded in an orderly fashion and through an appropriate terminology. It is a useful model for future investigators to follow. Unfortunately, several of the figures are too small to reveal the detail that they were intended to illustrate. A brief key separates the genera *Hemirhipus* and *Tetrigus*.

LANCHESTER, H. P., 1939: This splendid paper on the morphology of the larva of *Limonium canus* LeConte is probably the most detailed record in the elaterid literature. It is intended as a basis for future comparative studies. The text is illustrated by 16 good-sized drawings, and there is no doubt that the study has been performed with much care. In several instances the author has departed considerably in his interpretation of structure, and consequently in his terminology, from that of such workers as Böving, Snodgrass, and Anderson. It is doubtful if this departure has enhanced the value of the contribution.

METHODS AND PROCEDURE

REARING

The primary purpose of the rearing project at the Saskatoon laboratory has been to associate larval and adult stages. Considerable information on the biology of certain species has been obtained, but this has been largely incidental to the main purpose. Through the cooperation of colleagues and friends more than 4,000 elaterids have been collected for rearing. Some 250 larvae have been reared to adults and 30 others to pupae. The reared adults represent more than 50 species, of which 20 belong to the tribe Lepturoidini and 7 to the genus *Ludius*.

In the Holarctic region most species of Elateridae pupate in July or early August, and best results have been obtained from collections made just prior to or during that period. Usually a high percentage of the large larvae collected at this time pupate within a few weeks, and in addition pupae and young adults may be found in their pupal chambers along with their larval exuviae.

The largest larvae of each type were selected for rearing. Only one specimen was put in each container, which usually was a 1-ounce, 2-ounce, or 3-ounce salve tin. In this way confusion was avoided in associating adults with larval exuviae and losses from disease and predatism were minimized. The containers were nearly filled with appropriate material such as soil, wood, or leaf litter, taken from the exact spot where the larvae were found. Potato, crushed wheat, and fresh grass roots were commonly used for food and predaceous species occasionally were given decapitated coleopterous and lepidopterous larvae. Small amounts of water were added weekly to each container to keep the contents just slightly moist. Most of the rearing was done at room temperature, but some specimens were reared in controlled-temperature cabinets operating at 60° F. to 80° F. Very little benefit was noted from maintaining the larvae at any constant temperature, and varying temperatures were not thoroughly tested.

Where exact data on pupation were desired, the pupa or prepupal larva was gently transferred from its pupal chamber to a depression made on the surface of the soil (or litter), where it could be observed daily with a minimum of disturbance. Glass-topped tins or glass vials, partially filled with moist soil or litter, were used occasionally as containers for specimens under daily observation. In every instance the last larval exuvium and the pupal exuvium were preserved.

PRESERVATION AND STORAGE OF MATERIAL

When only one or two larvae of an unreared type were collected, none was preserved until after some attempt had been made to rear them, but care was taken to preserve immediately any specimens that died. When more than two larvae of the same type were collected, some were preserved at once for morphological purposes, at least one large specimen being included if there were several available.

Several different preservatives were used, but 70 percent ethyl alcohol was found to be satisfactory. Preservatives containing acetic acid distended the larvae and made them more suitable for morphological study, but the acid tended to destroy the muscles after the material had been preserved for a year or more.

Larvae and the exuviae of reared specimens were placed in small shell vials which were plugged with cotton batting and stored in pint fruit jars. Each vial contained a place-date-collector label and the record number of the specimen. The latter permitted cross reference to collecting notes and, in the case of reared specimens, insured accurate association with adults. The exuvium of a reared specimen was always kept in a separate vial and the date of emergence of its adult was recorded on the date label. Preservative was added both to the vials and fruit jars, thus giving double protection against desiccation.

Reared adults were pinned and labeled with exactly the same information as was given on the labels with their exuviae. All such adults were stored in a special collection and were not incorporated into the working collection of the laboratory.

PREPARATION OF MATERIAL FOR EXAMINATION

The general procedure followed in the preparation of the material of each species was to mount on slides the head parts of one or more specimens, then to soak the remainder of the specimen in 10-percent KOH until all muscles and viscera could be squeezed out and the specimen fully distended to reveal the sclerites of the thorax and abdomen. Such specimens were then returned to alcohol and used to supplement observations made upon entire larvae. Specimens for dissection were carefully selected to avoid badly eroded mouthparts. In many instances, parts of the thorax and abdomen were placed upon slides, and for *Ludius aeripennis destructor* the head parts of many specimens were dissected and all parts of at least one larva were mounted. Dissected parts were placed in 10-percent KOH for a few

hours, then thoroughly rinsed in water and put in 95-percent alcohol for several minutes before mounting in Canada balsam.

The study of the mandibles was facilitated, in many instances, by fastening each one with seccotine to the tip of a minuten pin, the base of which had been thrust into the small end of a cork. By inserting the cork into a vial the mandible could be stored safely. Mounts of this type were particularly useful in observing sculpture, of which only a limited view could be had from slides.

KOH was used to distend dry, hard, shriveled larvae and to soften larval exuviae so they could be made ready for examination. Ethyl acetate was also used for softening larval skins. One or two drops of ethyl acetate in a concave-bottomed dish was found helpful in manipulating small sections of exuviae under the binocular.

EXAMINATION OF MATERIAL

The material was examined by two distinct methods: first, a preliminary survey to determine the general relationships of the species that had been assembled, and second, a detailed study to obtain separating characters for closely related groups and species.

THE RECONNAISSANCE SURVEY

When the great bulk of the material had been assembled and the preparation of slides was well advanced, a comprehensive morphological survey was undertaken. This included all available species of the tribe Lepturoidini. By the method of comparative morphology a careful examination was made of the mandibles, nasale, subnasale, frons, paranasal lobes, gula, prosternum, number of spinelike setae on the episterna of the mesothorax and metathorax, setal pattern on abdominal mediotergites, "impressions" and other sculpturing of abdominal mediotergites, general type of pleural and sternal structures, and the ninth and tenth abdominal segments. Each structure was examined independently in all species before examination of the next structure was begun. Throughout this survey descriptive notes were made, numerical data tabulated, and numerous careful preliminary drawings prepared. At this time one specimen of each species was examined, rarely more. Some attempt was made to group the species on the basis of each of the above characters, and a preliminary arrangement of "species groups" was deduced from the entire evidence.

THE DETAILED STUDY

The detailed examination of *Ludius* was begun by preparing a comprehensive illustrated description of *Ludius aeripennis destructor*

Brown. Other species of the *aeripennis* group were compared with this description and differences noted and illustrated. This procedure was followed for each "species group," in each case the species described in full being that for which there was the most suitable material.

In the study of the genera related to *Ludius*, only generic and "species group" descriptions were prepared. Several specimens of each of these species were examined carefully, but particular attention was given to some 30 characters selected on the basis of the reconnaissance survey and the detailed work with *Ludius*.

Descriptions.—All descriptions were made from preserved specimens, but living material was examined when available. The largest and most perfect specimens were selected as the primary basis for each description. All these (usually from three to six specimens where available) were thoroughly examined. The remaining specimens were used extensively in determining the individual variation, especially in characters of setation and sculpture. After the morphological data were analyzed the descriptions were revised to eliminate details common to all species. Each revised description was then checked by a complete reexamination of a few larvae picked at random from the available material. All specimens were examined in checking the characters ultimately regarded as diagnostic.

The head and mouthparts were examined under the compound microscope using low and high power and occasionally oil immersion. Most of the remaining parts were described from binocular examination, using a magnification of 64 diameters in studying the sculpture and setae. Fine punctation is more readily observed on living specimens; consequently the preserved material was very carefully examined for the presence of minute pits. Such sculpturing, as well as minute setae, was best observed by firmly gripping the larva with tweezers and rotating it slowly while it was focused in strong light.

The detailed descriptions are believed to be highly accurate, but minute pores and minute setae are difficult to observe and subject to considerable individual variation, the extent of which often was not fully determined. These characters have been retained in the descriptions for the sake of completeness, but rarely are they used as a basis of identification.

Illustrations.—Each figure is drawn from a single specimen and is not a composite made up from observations on several individuals. All drawings were made by the aid of an eyepiece micrometer and cross-section paper. To facilitate comparison, a microprojector was

used to a considerable extent in the preparation of preliminary sketches of head parts, but none of these sketches were used as final illustrations.

A millimeter scale indicates the magnification of the drawings of whole larvae, but with few exceptions this is not done for the illustrations of larval parts. The writer finds himself in close agreement with Blackwelder (1936, p. 7) who states, ". . . the magnification attained . . . is believed to be purely incidental and of no importance to a knowledge of the morphology."

ABBREVIATIONS USED IN ILLUSTRATIONS

To clarify the terminology adopted, the list of abbreviations used in the illustrations has been expanded to include the equivalent terms that commonly appear in the literature. In addition, the less familiar terms are defined and the source of the term or of its definition is given in parentheses.

<i>a:</i>	Anal aperture.
<i>aed:</i>	Dorsal anteroepicranial setae (Hyslop and Böving, 1935, p. 49).
<i>aev:</i>	Ventral anteroepicranial setae (Hyslop and Böving, 1935, p. 49).
<i>al:</i>	Anal lobe.
<i>ant:</i>	Antenna.
<i>ar:</i>	Anal armature (= "scansorial hooks" auct.).
<i>atm:</i>	Medial anterotergal seta.
<i>br:</i>	Brace.
<i>cd:</i>	Cardo.
<i>cn:</i>	Caudal notch: the interspace between urogomphi (Comstock and Slingerland, 1891).
<i>co:</i>	Condyle.
<i>cr:</i>	Crease.
<i>cv:</i>	Cervical sclerite (= "parietal", Lanchester, 1939, fig. 1 A, <i>par.</i>).
<i>cx:</i>	Coxa.
<i>dg:</i>	Dorsal groove of mandible.
<i>distp:</i>	Dististipes: "An anterior portion of the maxillary stipes" (Böving and Craighead, 1931, p. 81).
<i>dm:</i>	Dorsal margin of inner face of distal part of mandible.
<i>dpla:</i>	Dorsal plate of ninth abdominal segment: the central dorsal area; in the biconvex type of elaterid larva, usually flattened, limited laterally by raised, carinate margins, anteriorly by transverse impression, posteriorly by caudal notch.
<i>dplf:</i>	Dorsopleural fold (= "dorso-pleural groove" or "dorso-pleural line" of Snodgrass, the "ventro-lateral suture" of Böving, and the "pleural suture" of Hopkins): ". . . a more or less distinct groove (or infolding) extending along each side of the abdomen below the line of the spiracles . . ." (Snodgrass, 1931, p. 10, fig. 3, <i>a-a</i>).

- dpr*: Dorsal prongs: conspicuous prongs placed anterad to urogomphi in larvae of the subfamily Oestodinae (fig. 8, c).
- ds*: Dorsal epicranial sulcus (Hyslop and Böving, 1935, p. 50).
- dsse*: Dorsosulcal setae (Hyslop and Böving, 1935, p. 50).
- e*: Eye spot.
- ephr*: Epipharyngeal rod.
- epla*: Epicranial plate (= "parietal," Whitehead, 1932, p. 230; "gena," Lanchester, 1939, fig. 1 A, *gen*). (Roberts, 1921, p. 202.)
- epm*: Epimeron.
- epst*: Episternum.
- eust*: Eusternum.
- ex*: Expanded medial margin of mandible (fig. 35, a).
- fc*: Frontoclypeal region (= "cephalic plate" of Roberts; "nasale and front" of Hyslop, 1917; "prae-frons" of Subklew, 1934b).
- fe*: Femur (= "tibia," Lanchester, 1939, fig. 5 A, t).
- fil*: "Filaments" (= "setae" auct.): setalike filaments, sometimes branching, on hypopharynx, laciniae, and other surfaces in the preoral cavity (figs. 3, g; 4, c, f).
- for*: Foramen magnum (= "occipital foramen" auct.): "The opening from the head into the neck" (Snodgrass, 1935, p. 127).
- fs*: Frontal suture.
- ga*: Galea.
- gula*: Gula: ". . . the area between the anteriorly extended lower ends of the postoccipital suture lying behind a line drawn between the posterior tentorial pits" (Anderson, 1936, p. 5).
- hph*: Hypopharynx.
- hphb*: Hypopharyngeal bracon: "A term introduced by A. D. Hopkins for a transverse brace between hypopharynx and the anterior part of the hypostomal margin" (Böving and Craighead, 1931, p. 82).
- hphr*: Hypopharyngeal rod: "Rod between hypopharyngeal sclerome and frons near antenna" (Hyslop and Böving, 1935, p. 59).
- hphsc*: Hypopharyngeal sclerome (= "closing plate," Lanchester, 1939, p. 14).
- hs*: Hypostoma: the ventral margin of each epicranial plate, between the ventral articulation of the mandible and the posterior tentorial pit.
- im*: Impression (= "muscular impression" of Schiodte, 1870).
- ipr*: Inner or lower prong of urogomphus.
- lac*: Lacinia.
- led*: Dorsal lateroepicranial setae (Hyslop and Böving, 1935, p. 49).
- lev*: Ventral lateroepicranial setae (Hyslop and Böving, 1935, p. 49).
- lig*: Ligula.
- lim*: Lateral impression.
- loim*: Longitudinal branch of impression.
- lsr*: Laterosternite: a lateral sclerotization of the sternum distinct from a principal median sternite.
- ltg I*: Laterotergite I (= "paratergite" or "epipleuron"): "A lateral sclerotization of the dorsum distinct from a principal median tergite" (Snodgrass, 1935, p. 81).

- ltg II:* Laterotergite II.
- ltga:* Anterior laterotergite (= "anterior mesopleurite or metapleurite," Lanchester, 1939, fig. 5 A, *pam*): an anterolateral sclerotization of the dorsum distinct from a principal median tergite.
- ltgp:* Posterior laterotergite (= "posterior mesopleurite or metapleurite," Lanchester, 1939, fig. 5 A, *ppm*): a posterolateral sclerotization of the dorsum distinct from a principal median tergite.
- mc:* Median carina of mandible: a small longitudinal toothlike ridge on the inner surface of mandible, anterior to retinaculum and between the ventral and dorsal margins.
- md:* Mandible.
- mg:* Median groove on dorsal plate of ninth abdominal segment.
- mst:* Mediosternite: a median sclerotization of the sternum distinct from lateral sternites.
- mtg:* Mediotergite: a median sclerotization of the dorsum distinct from lateral tergites. (After Snodgrass, 1935, fig. 139 B, *mtg.*)
- mtu:* Median tuft of filaments between maxillulae of hypopharynx.
- mxul:* Maxillula (= "superlingua" or "paraglossa" auct., or "horns of the hypopharynx" of Roberts, 1921, p. 206): lateral lobes of the hypopharynx.
- n.* Nasale (= "clypeus" of Schiodte, 1870): an anterior and median projection of frontoclypeal region (Böving and Craighead, 1931, p. 84).
- ns:* Nasal sulcus (= "nasal depression," Lanchester, 1939, p. 10): a more or less linear depression on frontoclypeal area running obliquely backward from junction of nasale and paranasal lobes.
- nsa:* Anterior nasosulcul setae: setae arising from anterior end of nasal sulcus, in the sinuosity between nasale and paranasal lobes.
- opr:* Outer or upper prong of urogomphus.
- ped:* Dorsal posteroepicranial seta.
- pen:* Penicillus (= penicillum): "A small setiferous process or bunch of hairs at the base of the mandible on the inner margin" (Roberts, 1930, p. 68).
- pge:* Postgenal area (= "paragenal area"): the lateral parts of the posterior region of the cranium.
- pim:* Paramedian impression on dorsal plate of ninth abdominal segment.
- pl:* Pleural area or pleurite (= "hypopleuron").
- plf:* Maxillary palpifer.
- plp:* Palpus.
- pmt:* Postmentum (= "mentum" or "submentum" auct.; "submentum + mentum," Horst, 1922, fig. 16, "su + men"; "postlabium," Lanchester, 1939, fig. 1 B, *lpo*): "The postlabium, or basal part of the labium proximal to the stipital region, or prementum; when sclerotized, containing either a single postmental

- plate, or a distal mental plate and a proximal submental plate" (Snodgrass, 1935, p. 156; adopted by Anderson, 1936, pp. 3 and 20).
- pnl*: Paranasal lobe (= "frontal angles" auct., "mandibular sclerite" of Henriksen, 1911, p. 227; "lateral wings of nasale," Lanchester, 1939, pp. 10-11, fig. 1 A, *nlw*): anterior projections of frontoclypeal area, on each side of nasale (Hyslop and Böving, 1935, p. 52).
- pnlp*: Cluster of pores on paranasal lobes (= "nasal sensory organs," Lanchester, 1939, p. 12).
- por*: Postoccipital ridge (Snodgrass, 1935, p. 128).
- pos*: Postoccipital suture (= "gular sutures") (Snodgrass, 1935, p. 128).
- prmt I*: First prementum (= "prementum" auct., "prelabium," Lanchester, 1939, fig. 1 B, *lpe*): anterior (visible) part of prementum in the Elateridae (Anderson, 1936, p. 20).
- prmt II*: Second prementum: posterior (invaginated) part of prementum in the Elateridae (Anderson, 1936, p. 20).
- pro*: Protuberance.
- prst*: Presternal area (= "acrosternite," Horst, 1922, p. 34; "brustschild," Korschelt, 1924, p. 533): the anterior area of the sternum in elaterid larvae, transverse in mesothorax and metathorax, triangular in prothorax; "prosternum" frequently used with reference to presternal area of prothorax.
- pstn*: Poststernellum: the most posterior part of sternum, lying behind sternellum (after Hyslop and Böving, 1935, fig. 9 A, *post*).
- pt*: Posterior tentorial arm.
- ptp*: Posterior tentorial pit (= "ventral tentorial pit" of Böving): "The external depressions in the cranial wall at the roots of the tentorial arms; . . . located . . . in the lower ends of the postoccipital suture" (Snodgrass, 1935, pp. 128-129).
- prstp*: Proxistipes: "A posterior portion of maxillary stipes" (Böving and Craighead, 1931, p. 84).
- ret*: Retinaculum (= "proximal lobe of mandible," Lanchester, 1939, fig. 4 C, *mpl*): "A hard, pointed, and tooth shaped process usually near or at the middle of the inner edge of the mandible; never jointed" (Schiodte's term, adopted by Böving and Craighead, 1931, p. 84).
- sap*: "Sensory" appendix of antenna (= "tactile papilla," "sensory process," "accessory process," or "supplementary joint").
- scl*: Sclerite.
- sen*: Sensillum: "A simple sense organ or one of the structural units of a compound sense organ" (Snodgrass, 1935, p. 549).
- sn*: Subnasale (= "subnasal process," Roberts, 1921, p. 205): the sclerotization on ventral aspect of base of nasale.
- snf*: Subnasal flap: wing-shaped membranous lining of the ventral surface of paranasal lobes and base of subnasale.
- soc*: Socket.
- sp*: Spiracle.
- spla*: "Sensory" plate in preoral cavity.

- spsc*: Spiracular sclerite: a laterotergite containing the spiracle.
- st*: Sternum.
- stl*: Sternellum: the part of sternum lying between the bases of coxae; limited anteriorly by eusternum and posteriorly by a line, real or imaginary, joining the posterior limits of attachments of coxae (after Hyslop and Böving, 1935, fig. 9 A, *stl*).
- stp*: Maxillary stipes (= "cardo plus stipes," Henriksen, 1911, fig. 2, "C + *St.m*," who was followed by Horst, 1922, fig. 16, "C + *stip*," and by Subklew, 1934b, fig. 2, "*CaSti*").
- t*: Tentorium.
- tal*: Talus (Hyslop and Böving, 1935, p. 52).
- tg*: Tergite.
- ti-ta*: Tibiotarsus (= "tarsus," Lanchester, 1939, fig. 5 A, *ta*): the tibia and tarsus united into one joint (after Hyslop and Böving, 1935, fig. 4, *ti-ta*).
- to*: Toothlike expansion on lateral aspect of ninth abdominal segment.
- tr*: Trochanter (= combined trochanter and femur of Lanchester, 1939, p. 33).
- trim*: Transverse impression or transverse branch of impression.
- tub*: Tubercle.
- un*: Ungula (= "dactylopodite" or "pretarsus" of Snodgrass). (Hyslop and Böving, 1935, p. 55.)
- ur*: Urogomphus (= "cercus" or "pseudocercus"): "A process, usually paired, projecting from the posterior end of tergum of the ninth abdominal segment. . . ." (Böving and Craighead, 1931, p. 85).
- vm*: Ventral margin of inner face of distal half of mandible.
- vmth*: Ventral mouthparts (= "lower jaw," Horst, 1922, pl. 1, fig. 4; "maxillo-labial apparatus," Guénat, 1934, p. 112): the entire unit formed by the fusion of maxillae and labium (after Böving and Craighead, 1931, pl. 84, fig. N).
- vr*: Ventral epicranial ridge.
- vs*: Ventral epicranial sulcus (= "hypostomal suture," Lanchester, 1939, fig. 1 B, *hs*). (Hyslop and Böving, 1935, p. 50.)
- vsse*: Ventrosulcal setae (Hyslop and Böving, 1935, p. 50).
- I to 10*: Abdominal segments.
- I, II, III*: Thoracic segments.

LISTING THE MATERIAL EXAMINED

The final criterion for the identification of larvae must be through their adults. Consequently, larvae that are not definitely associated with available reared adults are of only secondary importance in a taxonomic study. In listing such material the information given for each species has been limited to the following: The total number of larvae examined; the general localities represented, such as States, provinces, or countries; and the institutions in which the specimens

are stored. However, for larvae which, through rearing, are associated with extant adults, there have been added detailed notes on place, date, collector, record number, and other related data.

In listing the material of each species that was examined, the following abbreviations are used to indicate the institution in which the material is stored:

- C.N.C.: Canadian national collection, Ottawa, Ontario. (Material stored temporarily in the Dominion Entomological Laboratory, Saskatoon, Saskatchewan.)
 B.M.: British Museum of Natural History, London, England.
 Pa.C.: Pennsylvania Agricultural Experiment Station collection, State College, Pa. (Material temporarily stored with C. A. Thomas, Kennett Square, Pa.)
 R.V.A.C.: Royal Veterinary and Agricultural College, Copenhagen, Denmark.
 U.S.N.M.: United States National Museum, Washington, D. C.
 van Emden: Private collection of Dr. Fritz van Emden, British Museum, London.
 W.W.: United States Wireworm Laboratory, Walla Walla, Wash.

MORPHOLOGY OF A TYPICAL LEPTUROIDINE LARVA

In conducting the study a first essential was to investigate thoroughly the structure of a typical lepturoidine larva and to develop an appropriate terminology for its description. *Ludius aeripennis destructor* Brown was selected for this purpose because it was available in abundance, because of its tremendous economic importance, because it represented a large section of the genus *Ludius*, and because it was an excellent example of the tribe Lepturoidini.

TERMINOLOGY

In developing a suitable terminology, the writer has drawn freely from the works of Snodgrass (1931, 1935), Hyslop and Böving (1935), Böving and Craighead (1931), and Roberts (1921, 1930). Anderson (1936) has been followed in naming labial structures.

A survey of the literature on the morphology of the larval Elateridae reveals much confusion and uncertainty in the naming of many parts. The hypopharynx, the ventral sclerites of the thorax, and the segmentation of the leg have always been a source of difficulty.

In the present study the hypopharynx is regarded as including both the basal sclerome at the mouth of the pharynx and the adjoining membranous area extending as far forward as the transverse fold at the base of the prementum.

Hyslop and Böving (1935, p. 55, fig. 9, *a*) have been followed in naming the major divisions of the sternum in the thoracic segments. Thus the anterior ventral sclerites are regarded as *presternum*; the area lying between the presternum and an imaginary line joining the furcal pits (observable in prothorax at inner anterior margins of bases of coxae, but not evident in mesothorax and metathorax) is designated *eusternum*; the *sternellum* lies behind the eusternum, between the bases of the coxae, being limited posteriorly by an imaginary or real line joining the posterior limits of the attachments of the coxae; the *poststernellum* is the extreme posterior part of the sternum, lying behind the sternellum. This interpretation seemed best since the homology of these sclerites has never been definitely established. However, it is pertinent to note that in the mesothorax and metathorax the "presternal sclerites" take a position suggestive of "intersternites" as interpreted by Snodgrass (1935, pp. 76, 78, fig. 39 A, *Ist*).

Hyslop and Böving (1935, p. 55, fig. 4) have also been followed in naming the segments of the legs: Coxa, trochanter, femur, tibio-tarsus, ungula.

MORPHOLOGY OF THE MATURE LARVA OF *LUDIUS AERIPENNIS*
DESTRUCTOR BROWN

Length 22 mm.; greatest breadth about 2.75 mm. on fourth and fifth abdominal segments. Fully distended larvae have measured 25 mm., but pupation has been recorded (Strickland, 1935, p. 521) when specimens attained a length of only 17 mm. Body robust; dorsum more convex than venter; slightly to moderately depressed dorso-ventrally, with large membranes on lateral aspect of thorax and abdomen; subparallel, with all segments broader than long, becoming narrower toward extremities; each segment widest just caudad to middle, constricted between segments. Head and ninth abdominal segment of approximately equal breadth (head slightly narrower), being about two-thirds to three-fourths greatest body width. Dorsum brownish yellow to bright yellow (near "clay color" or brighter, Ridgway, 1912), venter slightly paler; mandibles, nasale, talus, and prongs of urogomphi darker; membranes white or creamy white. Dorsum slightly rugose, sparsely punctulate. Median dorsal suture traverses all thoracic and first 8 abdominal segments, interrupted in each segment in region of longitudinally striated caudal margin.

HEAD (figs. 1, *a, b*; 2, *g*) prognathous; medium-sized; subquadrangular, with strongly arcuate sides; broader than long, widest across

middle; exclusive of appendages, almost as thick at base as long, thinner anteriorly, maximum thickness about one-third thickness of fully distended abdomen; flattened above and below; gular area depressed.

Frontoclypeal region (*fcl*, fig. 1, *a*) well defined by distinct frontal sutures (*fs*); bearing few fine punctures. Anterior part transverse, extending laterally to bases of antennae; posterior portion longitudinal, spatulate, extending backward to or almost to foramen magnum (*for*), truncate posteriorly. Two prominent nasal sulci (*ns*) run obliquely backward from junction of nasale and paranasal lobes, decreasing in depth posteriorly, each bearing 2 prominent setae anteriorly, designated the anterior nasosulcal setae (*nsa*). Other setae present as indicated in figure 1, *a*. *Nasale* (*n*, figs. 1, *a*; 2, *c*) well developed, unidentate, terminating sharply when uneroded; strongly sclerotized. *Subnasale* (*sn*, fig. 2, *c*) consisting of strongly sclerotized transverse ridge, ventrally convex; serrate, when uneroded, with a row of approximately 8 or 9 subequal, short, sharp, forward-projecting denticles; most lateral denticles usually slightly larger, occasionally projecting beyond lateral margins of nasale. *Paranasal lobes* (*pnl*, fig. 1, *a*) strongly produced anteriorly, usually extending slightly beyond nasale; anterolateral corner extending farther forward than rest of lobe; inner margin moderately to strongly convex; outer margin straight to moderately concave; anterior ventral margin densely pilose; dorsal surface bearing 3 setae (1 very small). *Talus* (*tal*, fig. 1, *a*) dark, condyle for mandible produced and strong; short apodeme projecting ventrad from lateral aspect, curving slightly laterad.

Epicranial plates (*epla*, figs. 1, *a*, *b*; 2, *g*) large, covering lateral, posterodorsal, and posteroventral surfaces of head; infolding posteriorly to form postoccipital suture (*pos*) and internally producing postoccipital ridge (*por*, fig. 4, *a*), which expands laterally into dark irregular plates applied to inside of head capsule. Sparsely and finely punctulate. Dorsally, with 2 shallow longitudinal sulci (*ds*), each with 5 setae (*dsse*) subequally spaced, the most anterior seta being very long and sometimes farther mediad, the next less than one-half as long, the 3 most posterior setae small. Ventrally with 2 strong ridges (*vr*) and sulci (*vs*) running backward from region of ventral articulations of mandibles, posteriorly forming lateral limits of postgenae; each sulcus bearing row of 7 to 14 setae (*vsse*), usually only 2 to 5 conspicuous. Laterally, midway between dorsal and ventral sulci, with 2 pairs of long lateroepicranial setae (*led*, *lev*) arising from pits

within cuticular depressions; minute, dark "sensory" structure just ventrad to each pair; sometimes with one or more minute setae caudad to ventral pair. *Eye spot* (*e*) black, well defined, ovate or circular, just caudad to ventral margin of base of antenna; surrounded by 4 or 5 setae, including the anteroepicranial setae (*aed*, *aev*) so designated by Hyslop and Böving (1935, p. 50). *Hypostoma* (*hs*, fig. 4, *a*) with strongly sclerotized mesal margins to which ventral mouthparts and hypopharynx attach. *Postgenal areas* (*pge*, fig. 1, *b*) expanded mesad, but always rather widely separated; glabrous.

Gula (*gu*, fig. 1, *b*) short, wide, glabrous; defined laterally by anterior extensions of postoccipital sutures (*pos*) which terminate in indistinct posterior tentorial pits (*ptp*) at bases of cardines.

Antennae (*ant*, figs. 1, *a, b*; 2, *g*; fig. 2, *a, d*) three-segmented. First joint (1) clavate, one-half to two-thirds as wide as long; without setae; 3 or 4 small pores. Second joint (2) subcylindrical, almost as wide as long; about one-half length of basal joint; without setae; 1 or 2 pores; a few small "sensory" pegs borne distally; 1 medium-sized conical "sensory" appendix (*sap*) just ventrad to base of third joint. Terminal segment (3) small, about half as long as second joint and one-third as wide; 4 setae on apex.

Mandibles (*md*, figs. 1, *a, b*; 2, *g*; fig. 2, *e, f, h*) alike, of moderate length, robust; two-thirds as wide at base as long; anterior half inward bending at an angle of approximately 45°; retinaculum (*ret*) well developed. Base triangular, mesally acute; well-developed condyle (*co*) and socket (*soc*) for articulation with epicranial plate and talus, respectively. Proximal half tapering distally; ventral surface slightly granular just laterad to penicillus; smaller granular area on dorsal surface; outer aspect with profound antennal fossa and two setae; penicillus (*pen*) present, sometimes reaching base of retinaculum. Distal half pointed; outer surface convex with deep dorsal groove (*dg*); inner face slightly excavate with small median carina (*mc*), sometimes worn away, ventral margin (*vm*) of inner face sharp and slightly convex ventrally, dorsal margin (*dm*) sharp and strongly convex dorsally.

Ventral mouthparts (*vmth*, fig. 2, *g*; fig. 9, *h*), excluding appendages, almost as long as sides of head; moving as a unit forward and backward, usually in a horizontal plane, with cardines acting as hinges; whole unit from two-thirds to three-fourths as wide at bases of stipites as at anterior ends of stipites.

Maxillae (fig. 3, *c*) well developed. *Cardines* (*cd*) moderately large, subtriangular, well separated; posteriorly attenuate, ending

with small dark condyle (*co*) articulating with small dark socket on tentorium. Each cardo with Y-shaped, sometimes V-shaped, brace (*br*) running forward from condyle, outer ramus defining lateral margin of cardo, inner ramus running slightly laterad to middle, reaching and articulating with base of stipes; small seta between rami of strengthening sclerotization. *Stipes* (*stp*) large, subrectangular, sides almost straight, base truncate; usually 5 or 6 prominent setae on antero-lateroventral aspect; 1 or 2 minute setae (or pegs) and scattered pores observable under high magnification. Proxistipes and dististipes not distinct, but distal part somewhat darker, ending anteriorly in whitish membranous or semimembranous palpi-fer (*plf*) supported dorsally by small subtriangular sclerite (*scl*, fig. 3, *f*); anterior dorsal aspect bearing a few branched hairlike filaments.² *Lacinia* (*lac*, fig. 3, *c*) elongate, anteriorly bluntly pointed; borne in almost vertical plane somewhat dorsal to galea, indistinctly defined proximally; densely clothed with long, yellow, branched seta-like filaments projecting into preoral cavity. *Galea* (*ga*, fig. 3, *c*; fig. 3, *d*, *e*) two-jointed. Basal joint (*1*) subcylindrical, usually only portions sclerotized; slightly shorter than terminal joint; without setae or pores. Terminal joint (*2*) narrower than basal segment; outer margin longer than inner margin; 3 to 10 pores on lateroventral aspect; tip (fig. 3, *d*) inclined inward, terminating in protrusible thimble-shaped membranous process bearing many "sensory" structures. *Maxillary palpi* (*plp*, fig. 3, *c*; fig. 3, *b*) four-jointed, all joints subcylindrical. First joint (*1*) wider than long; distally on mesoventral surface with group of 4 small pores, 1 relatively large seta and 1 small seta (sometimes 1 or 2 additional minute setae). Second joint (*2*) wider than long, almost equal in size to first joint; without setae; two pores. Third joint (*3*) wider than long, about one-half length of second joint; two pores ventrally; distally with 1 small seta on mesoventral aspect and 1 near lateral aspect. Fourth joint (*4*) at least as long as wide; nearly as long as third joint; with 1 minute seta and 1 pore dorsally; group of minute "sensory" papillae on apex (fig. 3, *a*).

Labium composed of postmentum and first and second prementum. *Postmentum* (*pmt*, figs. 1, *b*; 9, *h*) elongate, sides subparallel, truncate anteriorly, bluntly rounded posteriorly. One long seta (some-

² These filaments are commonly referred to as "setae," but being unarticulated at the base they are not true setae in the generally accepted sense (Ferris, 1934, p. 145). Similar branched filaments are found on laciniae, prementum, hypopharynx, and elsewhere in the preoral cavity.

times also 1 smaller seta) at each corner; sometimes 1 or more tiny setae along lateral margins; a few minute pores scattered over surface. *First prementum* (*prmt I*, fig. 1, *b*; fig. 3, *i*, *k*) visible; pentagonal; usually with 3 prominent setae just caudad to base of each palpus, making transverse row of about 6 hairs; 2 small setae posteriorly, 1 near each lateral margin; 6 to 10 pores scattered over anterior half of ventral surface; anterior dorsal surface membranous, with 8 to 10 minute peglike "sensilla" (fig. 3, *h*); posterior dorsal aspect densely clothed with branching setalike filaments (similar to filaments on maxillae and hypopharynx). *Second prementum* (*prmt II*, fig. 3, *i*) small, transverse, firmly united to first prementum; invaginated within distal end of postmentum. *Labial palpi* (*1*, *2*, fig. 3, *k*) two-jointed. Basal joint (*1*) cylindrical; one-half as long as prementum; about as long as wide; sometimes with 2 or 3 small, fine setae distally on lateral aspect (observable only under high magnification and frequently absent); about 4 pores ventrally. Terminal joint (*2*) small, approximately one-half length and less than one-half width of basal segment; without setae; usually with 1 pore; group of minute papillae on apex (fig. 3, *j*). *Ligula* (*lig*, fig. 3, *i*, *k*) reduced to small, membranous, anterior protuberance and pair of forward-projecting setae inserted between bases of palpi.

Hypopharynx (*hph*, fig. 3, *f*; fig. 3, *g*) posteriorly limited by dark, strong, transverse hypopharyngeal sclerome (*hphsc*) with ends attached ventrally to anterior end of hypostoma by thickened membranous bracons (*hphb*) and dorsally to mesal aspect of talus by very fine membranous rods (*hphr*) difficult to observe. Maxillulae (*mxul*) membranous, lobe-shaped, projecting forward with lateral edges expanding ventrally; clothed with long, fine branching setalike filaments (*fil*, fig. 3, *g*; fig. 4, *c*). Median tuft (*mtu*) of filaments projects forward from between maxillulae. Anterior portion of hypopharynx membranous, bearing numerous branching filaments.

Preoral cavity (fig. 4, *d*) large, lined with membrane attached dorsally to under surface of paranasal lobes and subnasale, laterally to mandibles, ventrally to hypopharynx and ventral mouthparts. Membrane soft and pliable except where thickened into connectives supporting hypopharyngeal sclerome. Mandibles move in V-shaped spaces between these membranous connectives to which they attach by folded membrane. Lining of dorsal surface consists mainly of transverse subnasal flap (*snf*, fig. 4, *d*; fig. 4, *f*) which together with the sclerotization of the subnasale possibly constitutes the epipharyngeal region (Hyslop and Böving, 1935, p. 52, footnote).

Subnasal flap is strengthened by two irregular "epipharyngeal rods" (*ephr*) with anterior margins drawn out into long setalike filaments (*fil*), some branching. Two small brown "sensory" plates (*spla*, fig. 4, *e*, *f*) lie directly caudad to sinuositities between nasale and paranasal lobes, posteriorly covered by membrane, anteriorly with 5 or 6 circular "sensilla." Remainder of dorsal lining covered by minute, pointed "sensilla" (*sen*) (base of each sensillum not articulated but continuous with membrane from which it arises), increasing anteriorly in density and in length, becoming setalike at anterior margin of subnasal flap. Ventral surface of preoral cavity well supplied with sensilla and branching filaments arising from dorsal aspect of labium and maxillae. Opening of mouth small, transverse, above base of hypopharynx; screened by sensilla and filaments of subnasal flap, hypopharynx, laciniae, prementum, and by penicilli of mandibles.

Tentorium (*t*, fig. 4, *a*; fig. 4, *b*) consisting of well-developed, unconnected posterior arms (*pt*) extending both forward and backward from region dorsad to posterior tentorial pits; posterior part of each arm produced straight backward to near base of head; anterior part ending freely in head cavity near posterolateral corner of hypopharyngeal sclerome. Short apodeme produced ventrally from lateral aspect of talus might represent vestigial anterior tentorial arm, being somewhat similar in position to structures in carabid larvae labeled by Böving (1910, p. 365, fig. 2, T) as "tentorium."

Cervical sclerites (*cv*, figs. 1, *a*; 2, *g*). Usually 2 subovate or subrectangular pale, indistinct sclerites dorsally at base of head, 1 on each side of middorsal line. Sometimes other indefinite, variable, and weakly sclerotized areas found farther caudad or laterad. One small stout seta on cervical membrane directly behind each dorsal epicranial sulcus (*ds*).

THORAX (fig. 5, *a*, *b*). Prothorax slightly more than three-fourths combined length of mesothorax and metathorax. All segments broader than long, each slightly wider and thicker than preceding segment.

Prothorax (*l*) wider posteriorly; slightly wider than long. *Tergites* (*tg*) not divided into medial and lateral sclerites as in mesothorax and metathorax; with anterior and posterior margins membranous and longitudinally striate; with scattered small shallow pits; without well-defined impressions; anteriorly with 7 to 10 setae (on each side of middorsal suture) arranged in transverse row, mostly in pairs; posteriorly with 5 to 8 setae in transverse row, usually ar-

ranged as 3 pairs with 1 unpaired seta farther laterad; usually without setae between anterior and posterior rows, sometimes 1 seta, rarely 2, near center of sclerite. *Episternum* (*epst*) large, anteriorly reaching sides of presternum; bearing 3 or 4 prominent setae and a few smaller hairs. *Epimeron* (*epm*) consisting of faintly striated membrane with small, narrow sclerite extending backward from point of articulation with episternum, bearing 1 to 3 small setae. *Presternal area* (*prst*) large, sclerotized, triangular, posteriorly acute; consisting of four sclerites as follows: A small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout bristle (sometimes also 1 small seta) laterad to center and a row of 5 minute setae or pegs on anteromedial aspect; and a very narrow, median, anterior piece, sometimes fused with lateral sclerites. *Eusternum* (*eust*) small, membranous or faintly sclerotized, bearing 2 tiny setae mesally; furcae (situated internally between bases of coxae) small, furcal pits shallow. *Sternellum* (*stl*) and *poststernellum* (*pstn*) indefinite, small, membranous.

Mesothorax (II, fig. 5, a, b) about twice as wide as long. *Mediotergites* (*mtg*) with posterior margins membranous and longitudinally striate; slightly rugose, with scattered small, shallow pits; *transverse branch of impression* (*trim*) reaching from one-eighth to one-fifth of distance from longitudinal branch to mediodorsal suture; *longitudinal branch of impression* (*loim*) very short or wanting. Anterior part of each mediotergite with 2 to 4 unpaired setae (most lateral usually longest) forming transverse row, with 1 seta within impression, 1 laterad to impression, and 1 or 2 between impression and mediodorsal suture; sometimes several minute hairs scattered across sclerite anterad to transverse branch. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, arranged as 2 pairs (sometimes with 1 small seta near more lateral pair). Lateral part of mediotergite with 1 pair of large setae between anterior and posterior rows. *Posterior laterotergite* (*ltgp*) large, subovate, in posterior half of segment, bearing 1 large seta anterad to center. *Anterior laterotergite* (*ltga*) well developed, subtriangular, one-half as large as posterior laterotergite; closely applied to anterolateral margin of mediotergite; 1 small seta ventrally; *spiracle* (*sp*) bifore, larger than spiracles in abdominal segments, broadest anteriorly. *Episternum* (*epst*) subtriangular; bearing several minute setae and armed along ventral margin with up to 10 spinelike setae, usually with 6 to 8. *Epimeron* (*epm*) as on prothorax, but usually with 1 or 2 more setae posteriorly. *Presternal area* (*prst*) transverse, convex

ventrally, consisting of 3 pale sclerites as follows: A small, inconspicuous, medial piece, variable in shape but usually subrectangular, glabrous; 2 larger lateral sclerites, subovate, more strongly sclerotized than medial piece, bearing many minute setae. *Eusternum* (*eust*) membranous or very faintly sclerotized, with transverse row of 6 to 10 fine setae (usually only 6 readily observable) and sometimes with 2 minute paramedian setae farther forward. Furcal pits absent. *Sternellum* (*stl*) membranous, glabrous. *Poststernellum* (*pstn*) membranous except for 2 inconspicuous, tiny, subtriangular posterior sclerites; glabrous.

Metathorax (*III*, fig. 5, *a, b*) very similar to mesothorax. *Anterior laterotergite* (*ltga*) without spiracle.

Legs (fig. 5, *b, d*) well developed, subequal in length, strong. *Coxa* (*cx*) sessile, oval, excavated on outer surface for reception of trochanter and femur; usually from 30 to 40 spinelike setae on anterior aspect, arranged in irregular longitudinal rows; several setae, some spinelike, scattered over posterior surface. *Trochanter* (*tr*) subcylindrical, outer face short, inner face about one-half length of coxa, with 10 to 15 spinelike setae and a group of 5 or 6 pores on medioanterior surface; 8 to 12 such setae and 1 fine seta scattered on medioposterior surface; 2 well-developed fine setae on medial aspect. *Femur* (*fe*) obliquely attached to trochanter; subcylindrical, outer face longest; about as long as trochanter, but slightly narrower; usually with 8 to 11 spinelike setae on medioanterior surface; 3 to 5 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. *Tibiotarsus* (*ti-ta*) subcylindrical, about as long as femur but narrower; 5 or 6 setae (some rather short and stout) around distal margin; 4 to 6 spinelike setae and 1 slender seta on medioanterior surface; 3 spinelike setae on posterior surface. *Ungula* (*un*) well developed, when uneroded almost as long as tibiotarsus; dark, curved; base expanded mediad; small medial sclerite at base, bearing 2 fine setae.

FIRST TO EIGHTH ABDOMINAL SEGMENTS (figs. 2, *b*; 6, *a, b, c*) subequal; when fully distended, each segment is almost as thick as wide; first segment shortest; fourth to sixth segments widest. *Mediotergites* (*mtg*) with scattered small, shallow punctures; posterior margins longitudinally striate. Prominent right-angled *impression* (*im*) on anterolateral aspect of each mediotergite, inner margin slightly sunken and pale, outer margin darker and somewhat sinuate; *transverse branch* (*trim*) curving slightly backward, on second to eighth segments extending approximately one-third distance from

longitudinal branch to middorsal suture, slightly shorter on first segment; *longitudinal branch (loim)* running parallel to lateral margin of sclerite, extending from one-half to three-fourths distance from transverse branch to posterior transverse row of setae. Anteriorly on each mediotergite 1 fine seta near medial end of impression and 1 small seta between end of impression and middorsal suture; sometimes a few minute setae scattered anterad to and mesad to impression. Posteriorly on each mediotergite, 3 pairs of long setae (only 2 pairs on first segment) forming transverse row, sometimes also 1 or 2 unpaired minute setae. Laterally, with 1 very small seta (frequently wanting) near posterior end of impression, and 2 (rarely 3 or 4) unpaired setae laterad to impression. *Laterotergite I (ltg I)* large, elongate, extending length of segment; heavily sclerotized; bearing 4 or 5 setae, 3 or 4 near dorsal margin and 1 near point of articulation with laterotergite II. *Laterotergite II (ltg II)* small; indistinctly defined and variable; articulating with anteroventral aspect of laterotergite I and extending forward to near anterior border of segment; glabrous. *Spiracular sclerite (spsc)* small, subovate, situated in anterior half of segment between mediotergite and laterotergite I; surface somewhat elevated just anterad to spiracle. *Spiracles (sp)* bifore, subequal in size; widest anteriorly; situated in posterior half of spiracular sclerite. Tergal and pleural areas separated by dorsopleural fold (*dplf*). *Pleurite (pl)* large, subovate, somewhat attenuate posteriorly; in posterior half of segment; strongly sclerotized; bearing 4 setae, one much longer than others; becoming gradually smaller from first to eighth segment. *Sternum (st)* usually of 1 piece, large, subquadrate, with faint longitudinal striations on posterior margin; with 2 faint anterior impressions (*im*) meeting mesally, and 2 prominent lateral impressions sometimes (especially on first abdominal segment) separating off laterosternites (*lst*); 8 to 14 setae, mostly around margins.

NINTH ABDOMINAL SEGMENT (figs. 6, *d*; 7, *a, d*), exclusive of urogomphi, about as long as eighth abdominal segment and four-fifths as wide; three-fourths as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch from two-thirds to three-fourths greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. *Dorsal plate (dpla)* irregularly lined and wrinkled; with small punctures (like pin pricks) sometimes increasing in size and density anteriorly; 4 shallow longitudinal impressions, 2 laterally (*lim*) and a paramedian pair (*pim*)

which converge posteriorly and usually meet in a short median groove (*mg*); without setae except at lateral margins, which are slightly raised and carinate, bearing 3 prominent blunt "teeth" (*to*), each with a long bristle; *transverse impression* (*trim*) usually rather weak, indefinite, and interrupted in middle, rarely continuing completely across segment as a somewhat wavy line bulging anteriorly at middle. Tergite (*tg*) continues uninterruptedly laterally and on posterior ventral surface; usually with from 18 to 25 unpaired setae (some small) on each side, some issuing from small, sclerotized tubercles; anteriorly on lateral aspect with a few small punctures, some with minute hairs. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-fifth of total length of segment (exclusive of urogomphi). *Pleural area* (*pl*) large, consisting of transversely striated membrane except at anterior end, where there is small ovate pleurite bearing several extremely minute setae. *Sternum* (*st*) of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite with from 9 to 14 setae, mostly in row around tenth abdominal segment; posterior margin membranous and striate, articulating with tenth segment.

Urogomphi (*ur*, figs. 6, *d*; 7, *a*, *d*; fig. 7, *b*, *c*) separate, bifid, short and stout; prongs short, robust, subequal. *Inner prong* (*ipr*) directed caudad in horizontal plane, turning slightly mesad, with short, sharp point turning upward and usually inward; prominent tubercle (*tub*) on ventro-caudolateral surface from inner margin of which a large bristle extends backward, another prominent seta issuing from just above inner margin of tubercle or from upper part of tubercle; 1 long seta ventrally at base of prong or slightly farther anterad; sometimes 1 or 2 minute setae around distal part of prong. *Outer prong* (*opr*) projected dorsad or caudodorsad with sharp, horny point inclined backward; 1 prominent seta on anterolateral aspect about halfway up prong; up to 10 short fine hairs around distal part of prong; 2 large setae ventrally at base or near base of prong, arising from upper margin of small tubercle. Undivided part of urogomphus with 1 stout seta ventrally near base. An occasional specimen has more setae on prongs than described above.

Caudal notch (*cn*) large, U-shaped, usually wider than long, somewhat narrowed posteriorly by incurving tips of inner prongs.

TENTH ABDOMINAL SEGMENT (*10*, figs. 6, *d*; 7, *d*) short, tubular, directed caudoventrad; terminal portion membranous, striate; with 2 whorls of about 10 fine setae, the more proximal whorl varying

from 8 to 14 hairs; without "armature" (= "scansorial hooks" auct.); anal aperture (*a*) linear and median.

KEYS AND DESCRIPTIONS

In using the keys and descriptions it is suggested that the following points be kept in mind: (1) The common structural differences between young and mature larvae of the same species; (2) the general dependability of the various taxonomic characters; and (3) criteria by which to appraise the adequacy of larval descriptions.

The characters presented in this study were taken from mature or nearly mature larvae wherever such were available. With less mature specimens certain structures will be found in relatively smaller numbers, e.g., setae, tubercles, denticles, and pits; and these and other structures in relatively smaller size, e.g., grooves, impressions, and small sclerites such as in a divided prosternum; whereas in very immature larvae some structures, especially the nasale, caudal notch, and urogomphi, may be of a quite different character. The number of larval instars through which individuals pass is known to vary so widely within a single species (Strickland, 1939) that no attempt has been made to determine or to suggest the relative maturity of the specimens examined. However, the key characters used are believed to hold for larvae of a considerable range of maturity, at least for all specimens that are more than half grown.

Every structure has potential taxonomic value. However, certain structures repeatedly have proved to be important, whereas others rarely have mattered. Differences in size and shape of definite sclerites such as the frontoclypeal area, prosternum, and pleurites are useful and entirely reliable features, whereas "sensory" structures such as pores, minute setae, and various sensilla are highly variable and only rarely are of taxonomic importance. Characters that are commonly used are briefly discussed below.

Size is a useful supplementary character, especially if a very large specimen is encountered. However, it must be used with considerable care because a shrunken larva might measure as much as one-fourth longer when fully distended, and many half-grown larvae would be within the size range of several species.

Body form has taxonomic value, but in the Lepturoidini many species have large lateral membranes that may be infolded or distended, thus changing the general shape of the specimen and impairing the practical value of the character. However, some species are normally flattened, others typically cylindrical; some are relatively

broad, others narrow; some are widest in the midabdominal region, others across the thorax. Within these limits the character is rather dependable.

Color differences usually are not reliable except between marked contrasts such as pale yellow or dark brown, not patterned or distinctly patterned, and larva unicolorous or dorsum much darker than venter. Allowance must be made for the lack of uniform expression and interpretation in the use of color and for the fact that mature larvae may be darker than younger individuals, recently moulted specimens are paler, and preserved material frequently becomes darker.

The ninth abdominal segment offers the most important diagnostic characters and should always be examined carefully, giving special attention to the caudal notch, the urogomphi, and the dorsal plate. Erosion may dull the points of the urogomphi, tubercles, and "teeth," but important specific and generic characters are more frequently drawn from this segment than from any other part of the larva.

Prominent sculpturing such as deep pits, transverse rugae, and tergal impressions appear to be reliable characters. Small or callow specimens have less conspicuous sculpturing than large or fully darkened specimens of the same species. The density of punctures and the length of impressions vary considerably and usually require observation on a good series of specimens to establish the common range of variation.

Setae often vary markedly both in number and in arrangement. However, they are usually reliable for distinguishing such contrasts as "setae absent or present" and "setae paired or unpaired." In specimens in good condition the setal arrangement on the abdominal mediotergites is generally dependable, but occasionally an individual is found with almost double the normal complement of hairs. Young larvae have fewer setae than older specimens. For these reasons, setal characters should be supported by other evidence where possible. The number of spinelike setae on the various segments of the legs and on the thoracic episterna should not be relied upon unless the differences are marked and constant.

The nasale is a very useful structure. It is subject to considerable erosion, but in the great majority of larvae the general type of nasale can be determined even when worn. Where there are small lateral denticles which soon wear away the structure loses much of its taxonomic value. However, workers should become familiar with all common types of nasale so that they can be recognized even when eroded.

The subnasale is a useful supplementary feature, but it is seriously eroded too frequently to be generally reliable.

Mandibles of distinct types provide splendid separating characters. Erosion dulls and shortens the points, but only minute carinae and denticles are likely to be completely worn away.

Antennae are of limited value. Sometimes the shape of the segments or their relative length is characteristic, but more often it is the number of "sensory" appendices on the second segment. This character is decidedly valuable, but as with many other sensory structures a knowledge of normal variation is essential to its proper use.

Eyes present or eyes absent is an excellent supplementary character, but the pigmented ommatidia may be displaced, especially in prepupal and premoult specimens. However, in species that have eyes the epicranial plate is not pigmented in the region normally occupied by the eye, and the presence of a clear spot at the appropriate location may be taken as evidence of the presence of eyes.

Spiracles are difficult to examine or to use except in their grosser aspects. Marked differences in size, shape, or position in the segment offer good characters, but the writer has found it impractical to attempt distinction on the basis of the number of transverse trabeculae. In fact, the basic structure of the bifore spiracle seems to be a controversial matter requiring further careful research.

The power to appraise descriptions and to use them is materially increased if one fully appreciates the main factors concerned in the making of adequate larval descriptions, namely, suitable material, detailed examination, and comparison with closely related species.

Suitable material must include larval exuviae of available reared adults, as proof of identification, but whole larvae are necessary for proper morphological examination. Several specimens of each species should be available so that individual variation can be appraised. The structures that vary and the degree of variation differ from species to species and cannot be predicted.

Detailed examination is essential. Experience has shown that larvae of closely related species are morphologically very similar. Specific characters frequently are inconspicuous and are entirely overlooked or inadequately described in a superficial study.

Wherever possible the study should be comparative and the comparison must include the closest allies known. This point is illustrated by the *Ludius* larvae occurring in Saskatchewan, where nine species are recognized in the larval stage. These belong to eight different

"species groups." Were these nine species described solely with reference to one another, a separation would be effected on the basis of group characters, not on specific characters, and the descriptions would likely be inadequate for separating these species from their close allies. Larvae of the same "species group" usually differ mainly in a certain set of characters which cannot be determined in advance. For example, in the *Ludius fallax* group specific identification depends primarily upon the relative length of the urogomphal prongs, the number of "sensory" appendices on the second segment of the antenna, and the shape of the posterior part of the frons, whereas in the *aeripennis* group such characters have no specific value and identification is made largely through the number of setae on the central dorsal area of the ninth abdominal segment. In describing a larva that has no known close allies there is no guide as to the structures that hold the greatest specific value and, therefore, there is less chance of preparing a description of lasting worth.

LARVAL CHARACTERISTICS OF THE FAMILY ELATERIDAE

The elaterid larvae are diverse in form, as shown in figure 8, but family recognition is possible, in almost every instance, by the following combination of characters: Thoracic legs present, well developed, subequal, five-segmented (counting the terminal claw as a segment); labrum absent or fused with clypeus and anterior margin of frons into a rigid nasale (*n*, figs. 1, *a*; 9, *a*, *j*); frontoclypeal area usually lyre-shaped (*fcl*, fig. 1, *a*; fig. 9, *a*, *j*); maxillae and labium elongate, and fused into a single unit (figs. 1, *b*; 9, *c*, *h*) with bases inserted far behind the articulation of mandibles; body straight with 9 abdominal segments visible dorsally, the ninth with or without paired terminal processes (urogomphi); the tenth abdominal segment bears the anus and lies ventrad (usually ventrocephalad) to the ninth and may or may not be armed with sclerotized structures; spiracles bifore. In the Cardiophorinae (fig. 8, *a*) each of the second to seventh abdominal segments is divided transversely into 3 pseudosegments.

A more extensive general description of an elaterid larva is given by Henriksen (1911, pp. 226-231; translated into English on pp. 278-283), and the family is separated in the larval keys of Roberts (1930) and of Böving and Craighead (1931). A working knowledge of the general morphology of elaterid larvae is given by Glen, King, and Arnason (1943).

KEY TO SUBFAMILIES OF THE ELATERIDAE AND TO TRIBES OF
THE SUBFAMILY PYROPHORINAE

1. Ninth abdominal segment with a median caudal notch (*cn*, fig. 8 *c*, *d*), sometimes small³ 2
Ninth abdominal segment without a median emargination (fig. 8, *a*, *b*).. 3
2. Ninth abdominal segment bearing 2 large dorsal prongs anterad to the urogomphi (*dpr*, fig. 8, *c*); nasale minute or wanting; mandibles with retinaculum; tenth abdominal segment without "armature"Subfamily **OESTODINAE**
Ninth abdominal segment without prongs anterad to urogomphi (figs. 8, *d*; 9, *i*; 10, *f*; 11, *g*); nasale well developed (*n*, fig. 9, *a*, *j*)Subfamily **PYROPHORINAE** 4
3. Abdomen with pseudosegmentation (fig. 8, *a*); mandibles deeply cleft into dorsal and ventral branches; spiracles placed upon retractile papillae; tenth abdominal segment bearing accessory anal lobes (*al*)Subfamily **CARDIOPHORINAE**
Abdomen without pseudosegmentation (fig. 8, *b*); mandibles with retinaculum; nasale well developed.....Subfamily **ELATERINAE**
4. Postmentum triangular (*pmt*, fig. 9, *c*)..... 5
Postmentum subrectangular (*pmt*, fig. 9, *h*)..Tribe **LEPTUROIDINI** (p. 33)
5. Mandibles without teeth on inner aspect (fig. 9, *d*, *e*); tenth abdominal segment usually with "anal armature" (*ar*, fig. 9, *i*)Tribe **PYROPHORINI**
Mandibles with 3 teeth on inner aspect.....Tribe **PITYOBINI**

LARVAL CHARACTERISTICS OF THE TRIBE LEPTUROIDINI

On the basis of larval characters, the tribe Lepturoidini includes the species separated by Leng (1920) into the tribes Lepturoidini, Hypnoidini, and Melanactini.

Hyslop (1917) characterized the tribe as follows: Postmentum broad caudad, mandibles with teeth on inner surface, and tenth abdominal segment without armature. There is no doubt that these are the primary diagnostic characters of this group. However, a more nearly complete characterization of a lepturoidine larva would be: Ninth abdominal segment emarginate posteriorly (*cn*, figs. 8, *d*; 10, *a*, *f*; 11, *a*) and without dorsal prongs anterad to urogomphi; tenth abdominal segment without armature; the bases of stipites distinctly separated and postmentum subrectangular (*pmt*, fig. 9, *h*); mandibles with 1 or more teeth on inner surface (figs. 2, *e*; 9, *f*, *g*); nasale well developed (*n*, figs. 9, *j*; 19, *b*); gula present (*gu*, figs. 1, *b*; 19, *f*; 27, *b*), sometimes very narrow; and cardines moderately large (*cd*, figs. 9, *h*; 22, *b*).

³ In larvae of the genus *Hemirhipus* (q.v. Böving and Craighead, 1931, pl. 84 G) the urogomphi are fused except at the tips, resulting in a small but distinct notch. In some first-instar larvae this notch may be closed (op. cit. pl. 85 O), but the line of fusion of the urogomphi is evident.

KEY TO GENERA, ISOLATED "SPECIES GROUPS," AND ISOLATED SPECIES OF THE TRIBE LEPTUROIDINI

1. Urogomphi undivided (*ur*, fig. 10, *a, b*) 2
 Urogomphi divided: prongs subequal (figs. 10, *f*; 11, *f*; 12, *a, f*), or unequal (figs. 11, *a*; 12, *b, c, e*) 3
2. Urogomphi blunt (fig. 10, *a*); abdominal pleurites absent (fig. 10, *c*) **Eanus** (p. 187)
 Urogomphi sharp (fig. 10, *b*); abdominal pleurites large. **Hypnoidus** (p. 186)
3. Head bearing dorsal posteroepicranial setae (*ped*, fig. 10, *g*); thoracic segments and first 8 abdominal segments bearing medial antero-tergal setae (*atm*, fig. 10, *g*) 4
 Without dorsal posteroepicranial setae; usually without medial antero-tergal setae 7
4. Ninth abdominal segment (fig. 10, *f*) with sharp "teeth" (*to*) on sides of dorsum and 2 setae on central dorsal area; Australia **Crepidomenus queenslandicus** Blair (p. 181)
 Ninth abdominal segment with well-rounded "teeth" on sides of dorsum and 4 setae on central dorsal area 5
5. Abdominal mediotergites (as in fig. 12, *d*) with conspicuous transverse rugae (crescent-shaped shallow pits, which are sometimes confluent); eyes absent; larvae attaining more than 30 mm. in length **Melanactes densus** LeConte (p. 189)
 Abdominal mediotergites without such sculpturing; eyes present 6
6. Abdominal mediotergites with transverse branch of impressions extending to or practically to the mediodorsal suture on second to eighth segments **Ludius**, the **nitidulus** group (p. 111)
 Abdominal mediotergites with transverse branch of impressions extending approximately one-half the distance from the longitudinal branch to the mediodorsal suture **Cryptohypnus** (p. 183)
7. Spiracles in eighth abdominal segment (*sp*, fig. 11, *e*) twice as long as spiracles in seventh abdominal segment **Ludius**, the **pyrrhos** group (p. 147)
 Spiracles subequal in size in seventh and eighth abdominal segments ... 8
8. Presternum of prothorax divided into 2 or more sclerites (*prst*, fig. 10, *d*) **Ludius**, **pars majora** (p. 35)
 Presternum of prothorax undivided, of 1 large triangular sclerite (*prst*, fig. 10, *e*) 9
9. Caudal notch small (figs. 11, *a, f*; 12, *b*) 10
 Caudal notch large (fig. 12, *a, c, f*) 16
10. Outer prongs of urogomphi reduced to mere tubercles (*opr*, fig. 11, *a, d*) **Limonius**, **pars** (p. 157)
 Outer prongs of urogomphi definitely pronglike (*opr*, figs. 11, *b, g*; 12, *b*) 11
11. Outer prongs of urogomphi not longer than inner prongs (fig. 11, *f-h*) 12
 Outer prongs of urogomphi much longer than inner prongs (fig. 12, *b*) 15
12. Ninth abdominal segment with a distinct (sometimes short) mediodorsal groove (*mg*, fig. 11, *f*); eyes present; North America 13
 Ninth abdominal segment without a mediodorsal groove (fig. 11, *g, h*); eyes absent in North American species 14

13. Outer prongs of urogomphi (*opr*, fig. 11, *b, f*) projected caudodorsad and usually slightly laterad, not curving anteriorly, tip blunt; abdominal mediotergites usually with impressions extending to the mediodorsal suture in second to fifth segments.....
**Ludius resplendens aerarius** (Randall) (p. 136)
- Outer prongs of urogomphi (*opr*, fig. 11, *c*) projected dorsad, curving anteriorly, tip sharp; abdominal mediotergites with impressions definitely not reaching to mediodorsal suture.....
**Elathous bicolor** (LeConte) (p. 167)
14. Ninth abdominal segment (fig. 11, *g*) with well-rounded "teeth" (*to*) on sides of dorsum.....**Limonius**, pars (p. 157)
- Ninth abdominal segment (fig. 11, *h*) with prominent pointed "teeth" (*to*) on sides of dorsum....**Ludius**, the *limoniiformis* group (p. 150)
15. Dorsum very dark, usually dark reddish brown to brownish black; abdominal mediotergites punctulate, but without transverse rugae; inner prongs of urogomphi (*ipr*, fig. 12, *b*) smooth, without posterior tubercles**Lepturoides** (p. 168)
- Dorsum never dark, usually yellow to yellowish brown.**Athous**, pars (p. 170)
16. Ninth abdominal segment (fig. 12, *e*) without a mediodorsal groove, with four setae on central dorsal area, and with very long outer urogomphal prongs (*opr*); without impressions on mediotergites of mesothorax and metathorax..**Ludius divaricatus** (LeConte) (p. 118)
- Ninth abdominal segment (fig. 12, *f*) with a mediodorsal groove (*mg*), and without setae on central dorsal area; with definite impressions on mediotergites of mesothorax and metathorax..... 17
17. Eyes absent; abdominal mediotergites (fig. 12, *d*) with prominent transverse rugae (crescent-shaped, shallow pits which are sometimes confluent); urogomphal prongs (fig. 12, *f*) subequal, outer prongs pointed when uneroded.....
**Hemicrepidius**, and **Athous niger** and its allies (p. 178)
- Eyes present; American species with prominent pits or rugae, European species sparsely punctulate; outer urogomphal prongs either with bluntly rounded tips (*opr*, fig. 12, *a*) or much longer than inner prongs (fig. 12, *c*).....**Athous**, pars (p. 170)

Genus LUDIUS Eschscholtz⁴

FIGURES 1-7; 8, *d*; 9, *h, j*; 10, *d*; 11, *b, e, f, h*; 12, *e*; 13-29

For many years nomenclatorial confusion has involved the insects now recognized under the generic name of *Ludius* Eschscholtz. Referring to this situation, Hyslop (1921, p. 621) states, "... the genus *Elater*, as recognized by contemporary coleopterists, is in reality the genus *Ampedus*, the insects now recognized under the

⁴Recent publications by Dietrich (1945, p. 19) and Lane (1948, p. 182) suggest that *Ludius* Eschscholtz should be placed in synonymy under *Ctenicera* Latreille. (Vide: Henry Dietrich, "The Elateridae of New York State," Mem. 269, Cornell Univ. Agr. Exper. Stat., Ithaca, N. Y., Jan. 1945; M. C. Lane, "Some Generic Corrections in the Elateridae I," Proc. Ent. Soc. Washington, vol. 50, No. 7, pp. 179-182, Oct. 1948.)

generic name *Ludius* being truly *Elater*. *Ludius*, on the other hand, should be applied to the insects generally known as *Corymbites*, and *Corymbites* as a generic name disappears." North American writers, in general, follow Hyslop and use *Ludius* instead of *Corymbites*, but European coleopterists still cling to the latter or to one or another of the subgenera recognized by Schenkling (1927). In the present study the name *Ludius* Eschscholtz includes all species of the following generic and subgeneric names: *Actenicerus* Kiesenwetter, *Anostirus* Thomson, *Aphotistus* Kirby, *Calambus* Thomson, *Corymbites* Latreille, *Ctenicera* Latreille, *Ctenicerus* Stephens, *Diacanthus* Latreille, *Haplotarsus* Stephens, *Hypoganus* Kiesenwetter, *Liotrichus* Kiesenwetter, *Prosternon* Latreille, *Selatosomus* Stephens, and *Tactocomus* Kiesenwetter.

Where possible, the names proposed by Brown (1935, 1936) for various "species groups" of *Ludius* have been used.

Knowledge of the larvae of the genus *Ludius* is based upon 44 species, 29 occurring in North America and 16 in Eurasia, one being common to both regions. All these, except 6 Eurasian species, have been examined in the present study.

The genus is extremely diverse, both in habit and in structure. Larvae occur normally in soil, decaying wood, and forest litter, but specimens have been found also in cow dung, mushrooms, and sphagnum, and under stones. Some species prefer dry situations, others require abundant moisture. In the world as a whole, *Ludius* is the most destructive genus in the Elateridae. But even the most phytophagous species seem capable of sustaining themselves for periods of months or years on decomposing organic matter, or of reverting to predaceous habits when opportunity or necessity arises. Some species are chiefly entomophagous and have never been associated with damage to cultivated plants. Larvae have been known to attack spiders, the active and inactive stages of various insects, and even members of their own species.

With the exception of a few pest species, the life history is either unknown or very incompletely known. On the basis of the information available, the common normal life cycle is as follows: The adults mate and lay their eggs in May and June; the eggs hatch within a few weeks; the larvae live for 3 or more years, pupating, when mature, in July or August; the adults develop within a month after pupation and remain in their pupal chambers until the following spring. Pupation occurs in June with some species, and undoubtedly other exceptions will be found as our knowledge of the biology of

the group increases. Only one record has been found in the literature to date of any species of *Ludius* (*L. ampliocollis*) normally completing its life cycle within 1 year.

Concerning the structural features of the genus *Ludius*, Henriksen (1911, p. 258) states (translation): "A genus which it is very difficult to define, as the known larvae show such variation in characters." The writer agrees fully with this statement. So much heterogeneity exists in the larvae assembled that no single character or combination of characters has been found which adequately defines the assemblage as a natural group.

However, all *Ludius* larvae examined have the urogomphi bifid and are thus distinguished from *Hypnoidus* and *Eanus*. Separation from *Cryptohypnus* and *Crepidomenus* is obtained for all known *Ludius*, except the *nitidulus* group, through the absence of dorsal posteroepicranial setae (*ped*, fig. 10, *g*). With the exception of seven species (*divaricatus*, *resplendens*, *sjaelandicus*, *pyrrhos*, *protractus*, *limoniiformis*, and *cylindriiformis*), all the *Ludius* examined have the prosternum divided and are thus separable from the larvae of *Limonius*, *Elathous*, *Lepturoides*, *Athous*, *Hemicrepidius*, and *Melanactes*. Of these seven species, *divaricatus* is quite isolated from other known Lepturoidini, and the other six probably are annectant species, as mentioned by Van Dyke (1932, p. 389), connecting *Ludius* with *Limonius* and with the *Athous* complex.

Because of these findings the writer feels justified in stressing the taxonomic value of characters of the prosternum. By combining the characters of the caudal notch and the prosternum, four major groups of *Ludius* have been established. These form a good working basis for the identification of the larvae of this genus.

Group I: Caudal notch small (fig. 14, *b, g*); prosternum divided into two or more sclerites (figs. 10, *d*; 13, *a*). This combination of characters is unique in the known Lepturoidini with the exception of *Eanus*, which is readily distinguished by the undivided urogomphi. This group includes the *cupreus* group, *appressus* (Randall), and *sjaelandicus* (Müller).

Group II: Caudal notch large (figs. 13, *h*; 14, *c, i, j*); prosternum divided into two or more sclerites (figs. 10, *d*; 13, *a*). *Cryptohypnus* and *Crepidomenus* larvae also possess these characters, but are distinguished by a combination of sculptural and setal patterns. This group includes two-thirds of the species of *Ludius* known in the larval stage: *aeripennis* group, *inflatus* group, *edwardsi* group, *semi-vittatus* (Say), *propola* group, *triundulatus* group, *fallax* group, *rotundicollis* group, *bipustulatus* (Linnaeus), and *nitidulus* group.

Group III: Caudal notch small (fig. 11, *f, h*); prosternum undivided, consisting of one triangular sclerite (fig. 13, *b*) sometimes deeply incised on posterolateral aspects. This combination of characters is found in all species of *Limoni*, *Elathous*, and *Lepturoides*, and in many species of *Athous*. Proper characterization of the *Ludius* that fall in this group can be made only on the basis of "species group" characters as given in the key to genera, isolated species groups, and isolated species of the tribe Lepturoidini (p. 34) or as discussed under the species groups concerned: *pyrrhos* group, *limoniiformis* group, and *resplendens aerarius* (Randall).

Group IV: Caudal notch large (fig. 12, *e*); prosternum undivided, consisting of one large triangular sclerite, much as represented in figures 10, *e* and 13, *b*. These characters are found in *Hypnoidus*, *Hemicrepidius*, *Melanactes*, and in some *Athous*. The only *Ludius* falling in this group is *divaricatus* (LeConte) and it is readily separated from other known Lepturoidini by the characteristic ninth abdominal segment (fig. 24, *c, d*).

Considering the genus in the broad sense in which it is currently recognized, the mature larvae may be described as follows, characters common to all species being marked with an asterisk:

Length 14 to 30 mm. Shape varying from the robust *pectinicornis*, measuring 28 mm. by 4 mm., to the relatively slender *cylindriciformis*, measuring 30 mm. by 2.6 mm. Body usually widest across fourth abdominal segment, but in some species widest across thorax and first 2 abdominal segments; some species very robust with relatively small pleural membranes, others flattened with conspicuous large pleural areas. Dorsum pale yellow to very dark brown; without color pattern or distinctly patterned. *Urogomphi always bifid. Urogomphal prongs varying tremendously as to shape and relative length. Caudal notch large or small; posterior aperture varying from wide to almost closed. *Dorsum of ninth abdominal segment always with "teeth" on lateral margins. Dorsal plate of ninth abdominal segment varying from very convex to almost flat, the following characters being present or absent: setae on central area, large pits, median groove, and transverse impression. Frontoclypeal region reaching to foramen magnum or failing to attain foramen; terminating truncate, broadly rounded, or bluntly pointed. Nasale of one tooth terminating in one or three points. Subnasale highly variable. Eyes present (usually) or absent; from 2 to 6 setae around each eye or eye region. From 2 to 7 lateroepicranial setae in unpaired or paired arrangement. Each dorsal head sulcus with 4 or 5 setae, sometimes additional minute setae. Gula short and wide, or short and narrow, or elongate and

narrow. *Antennae with basal segment longest and terminal segment shortest. One to 6 "sensory" appendices on second segment of antenna. *Mandibles with well-developed retinaculum and without other prominent teeth. Proxistipes and dististipes not distinct except in *rotundicollis* group. From 2 to 8 prominent setae on antero-latero-ventral aspect of stipes. *Second segment of maxillary palpi without setae. Postmentum with 1 or 2 setae at each corner. *Second segment of labial palpi not longer than first segment. Presternum of prothorax of 1, 2, 3, or 4 sclerites. Each episternum of mesothorax and metathorax without spinelike setae or bearing from 1 to 10 such setae. Legs bearing many spinelike setae, number and arrangement variable. *Abdominal mediotergites (segments 1 to 8 inclusive) usually punctulate without prominent transverse rugae or large deep pits. Abdominal mediotergites bearing "impressions," length variable; setal pattern highly variable in both number and arrangement. Abdominal pleurites vary from "almost wanting" to well developed. Sternum in first to eighth abdominal segments either of 1 or 3 sclerites. Abdominal spiracles usually subequal and in anterior half of each segment; sometimes in posterior part of eighth segment; sometimes enlarged in eighth segment. Tenth abdominal segment with anal aperture linear or T-shaped.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF *LUDIUS*⁵

- | | | |
|-----------------|---|---------------------------------------|
| 1. | Caudal notch large (figs. 13, <i>h, i</i> ; 14, <i>c, i</i>)..... | 2 |
| | Caudal notch small (figs. 11, <i>f, h</i> ; 14, <i>b, g</i>)..... | 12 |
| 2. | Presternum of prothorax divided into 2 or more sclerites (<i>prst</i> , figs. 10, <i>d</i> ; 13, <i>a</i>); eyes present (indistinct in <i>edwardsi</i> and <i>semi-vittatus</i> groups) | 3 |
| | Presternum of prothorax undivided, of 1 large triangular sclerite (<i>prst</i> , fig. 13, <i>b</i>); eyes absent; ninth abdominal segment (fig. 12, <i>e</i>) as figured..... | <i>divaricatus</i> (LeConte) (p. 118) |
| 3. ⁶ | Urogomphi with tips of outer prongs sharp and inclined backward (<i>opr</i> , fig. 13, <i>d, e, f, i</i>); spinelike setae present on episterna of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae arranged in pairs (fig. 14, <i>e, f</i>) (species primarily phytophagous) | 4 |

⁵ This key does not include the European species *Ludius melancholicus* (Fabricius), *L. amplicollis* (Germar), and *L. affinis* (Paykull). Larvae of these species were not available for examination and key characters and relationships are not known. For descriptions of these species see pp. 64, 64, 93, respectively.

⁶ In this couplet, any one of the three characters listed will provide proper separation of the larvae. The urogomphal prongs are most readily observed, but this character must be used with care because the tips of the prongs are sometimes worn off.

- Urogomphi with tips of outer prongs either bluntly rounded (*opr*, figs. 13, *g*; 14, *j*); or sharp and inclined upward, inward or forward (figs. 13, *c*; 14, *i*); without spinelike setae (usually with a few very fine setae) on episterna of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae not definitely "paired" (fig. 14, *d*) (species primarily predaceous)..... 7
4. Prongs of each urogomphus like grappling hooks (fig. 13, *e*); eyes usually small and indistinct..... 5
- Urogomphal prongs of different type (fig. 13, *d*, *f*); eyes usually clearly visible 6
5. Pleurites in first abdominal segment practically as long as sternal plate.....**semivittatus** (Say) (?) (p. 66)
- Pleurites in first abdominal segment less than three-fourths as long as sternal plate.....the **edwardsi** group (p. 56)
6. Urogomphi and prongs relatively short and thick (fig. 13, *d*, *i*); two pairs of lateroepicranial setae.....the **aeripennis** group (p. 41)
- Urogomphi and prongs relatively long and slender (fig. 13, *f*, *h*); only three prominent lateroepicranial setae.....the **inflatus** group (p. 49)
7. Ninth abdominal segment with prominent pits on dorsum (fig. 14, *j*); proxistipes and dististipes distinct (fig. 14, *h*).....
-the **rotundicollis** group (p. 94)
- Ninth abdominal segment lacking prominent pits (fig. 14, *i*); proxistipes and dististipes not distinct..... 8
8. Conspicuous color pattern on dorsum; urogomphi (fig. 14, *c*) with inner prongs (*ipr*) large and broadly rounded at tips.....
-**bipustulatus** (Linnaeus) (p. 106)
- Without conspicuous color pattern; inner urogomphal prongs with sharp tips (*ipr*, fig. 14, *i*)..... 9
9. Outer prongs of urogomphi with sharp tip curving forward (*opr*, fig. 13, *c*); prongs subequal or outer prongs longer; only one "sensory" appendix on second segment of antenna..... 10
- Outer prongs of urogomphi of different type (*opr*, fig. 13, *g*); prongs subequal or inner prongs longer; normally with more than one "sensory" appendix on second segment of antenna..... 11
10. Ninth abdominal segment (fig. 14, *i*) with setae (usually four) on central dorsal area; head with dorsal posteroepicranial setae (*ped*, fig. 10, *g*); nasale tridentate at tip.....the **nitidulus** group (p. 111)
- Ninth abdominal segment without setae on central dorsal area; head without dorsal posteroepicranial setae; nasale unidentate.....
-the **propola** group (p. 67)
11. Abdominal mediotergites (fig. 14, *d*) with impressions (*im*) extending to mediodorsal suture on second to fifth segments; nasale unidentate; larvae yellowish brown.....the **triundulatus** group (p. 75)
- Abdominal mediotergites with transverse branch of impressions extending about three-fourths of distance from longitudinal branch to mediodorsal suture; nasale tridentate at tip; larvae brown to dark brown.....the **fallax** group (p. 82)
12. Presternum of prothorax divided into 2 or more sclerites (*prst*, figs. 10, *d*; 13, *a*)..... 13
- Presternum of prothorax (fig. 13, *b*) undivided, of 1 large triangular sclerite, sometimes rather deeply incised on lateroposterior aspects.. 15

13. Spiracles in eighth abdominal segment (*sp*, fig. 14, *f*) situated relatively much farther caudad than in seventh abdominal segment; abdominal pleurites well developed.....*sjaelandicus* (Müller) (p. 142)
Spiracles in same relative position in all abdominal segments; abdominal pleurites small and indistinct..... 14
14. Spinelike setae present (usually 2 to 4) on episterna of mesothorax and metathorax; urogomphi (fig. 14, *g*) as figured.....
.....the *cupreus* group (p. 124)
Without such spinelike setae; urogomphi (fig. 14, *a, b*) as figured....
.....*appressus* (Randall) (p. 135)
15. Spiracles in eighth abdominal segment (*sp*, fig. 11, *e*) at least twice as long as spiracles in seventh abdominal segment.....
.....the *pyrrhos* group (p. 147)
Spiracles in seventh and eighth abdominal segments subequal in size.... 16
16. Dorsum of ninth abdominal segment (fig. 11, *f*) with blunt "teeth" (*to*) on lateral aspects, and with median groove (*mg*); eyes present*resplendens aerarius* (Randall) (p. 136)
Dorsum of ninth abdominal segment (fig. 11, *h*) with sharp "teeth" (*to*) laterally, and without median groove; eyes absent.....
.....the *limoniiformis* group (p. 150)

THE LUDIUS AERIPENNIS GROUP

FIGURES 1-7, 9, *h, j*; 10, *d, i*; 14, *e*; 15

KEY TO SPECIES

1. From North America..... 2
From Europe or Asia..... 4
2. With 4 setae on central dorsal area of ninth abdominal segment (fig. 15, *a*)*pruininus* (Horn) (p. 45)
Without such setae (fig. 7, *a*)..... 3
3. Western North America.....*aeripennis* (Kirby) (p. 42)
Eastern North America.....*appropinquans* (Randall) (?) (p. 44)
4. With 2 setae on central dorsal area of ninth abdominal segment (fig. 15, *f*)*latus* (Fabricius) (p. 48)
Without such setae.....*aeneus* (Linnaeus) (p. 46)

Larvae of this group are known for the five species listed in the key above. With the exception of *appropinquans*, which was collected from leaf litter, all are soil inhabiting, preferring well-drained soils, and are extremely important pests, especially of grain crops. The larval life lasts for at least 3 years. Pupation occurs normally in July or early August. The adults are fully formed within 2 to 4 weeks after pupation occurs, but they usually remain in their pupal chambers until the following spring.

This group belongs to that larger association of *Ludius* that combine a large caudal notch and a divided prosternum. Closely related species are found in the *inflatus* group, but separation is readily

achieved through characters of the ninth abdominal segment (figs. 7, *a*; 15, *a, f*; 16, *a*), impressions on the mesothorax and metathorax, and through other differences discussed under the *inflatus* group (p. 49).

When mature, the larvae usually exceed 17 mm. in length. Dorsum yellowish brown to bright yellow. Caudal notch large, U-shaped. Urogomphi bifid, short and thick; prongs subequal in length with sharp, horny tips; tip of outer prong usually inclined backward, but not continuing downward as in the *edwardsi* group. Ninth abdominal segment with 3 or 4 prominent blunt tubercles or "teeth" on lateral margins of dorsal plate, no setae or 2 or 4 setae on central dorsal area, and distance between caudal notch and pleural area equal to one-sixth to one-fifth total length of segment exclusive of urogomphi. Nasale unidentate. Frontoclypeal area truncate posteriorly. Eyes well developed. Two pairs of lateroepicranial setae on each gena. Gula short and wide. Mandibles robust, as in figure 2, *e, f, h*. Second segment of antenna with one "sensory" appendix. Basal segment of labial palpi without setae. Presternum of prothorax divided into 3 or 4 sclerites. Mesothorax and metathorax with short impressions (indistinct in *pruininus*) on mediotergites, and with several spinelike setae (up to 10) on each episternum. Mediotergites of second to eighth abdominal segments with transverse branches of impressions usually attaining less than one-half of distance from longitudinal branches to middorsal suture, and with prominent setae arranged in pairs. Spiracles in anterior parts of segments.

LUDIUS AERIPENNIS (Kirby)

FIGURES 1-7; 9, *h, j*; 10, *d*; 13, *d*; 14, *e*

Elater aeripennis KIRBY, in Richardson's Fauna Boreali-Americana, vol. 4, p. 150, 1837.

Corymbites tinctus LECONTE, Proc. Acad. Nat. Sci. Philadelphia, p. 85, 1859.

Ludius elegans SCHWARZ, Wytzman, Genera Insectorum, pp. 46, 225, 322, 1907.

Ludius aeripennis (Kirby), BROWN, Canadian Ent., vol. 67, pp. 127-129, 1935.

This western species ranges from Alaska to Oregon and as far east as Manitoba and the Dakotas, probably including western Minnesota. The subspecies *destructor* Brown (Brown, 1935b, p. 129), referred to in the earlier economic literature as *tinctus* (LeConte) or as *aeripennis* (Kirby), is widespread and abundant over the prairie areas and adjoining parklands, but is replaced by the typical *aeripennis* in the forested and mountainous regions to the north and west. Both subspecies occur in the Peace River area of Alberta and British Columbia, *destructor* predominating in the open grassland sections.

The typical *aeripennis* has been associated with damage to wheat in the Peace River Block and is a pest, especially of truck crops, along the Pacific coast and in the inland mountain valleys. In northern Saskatchewan forests the larvae have been collected in moist sandy soil just under the surface litter and have been associated with plant injury when such areas have been brought under cultivation.

The subspecies *destructor* is a major pest in fields (King, 1928, pp. 702-703; King et al., 1940) and gardens (Glen and King, 1938; Munro and Schifino, 1938), the larvae being most abundant in loam or silty soil and in fields which have been cropped to grains or grasses for 5 or more years without summer-fallowing. Irrigated land in southern Alberta is less severely infested with this wireworm than is unirrigated land. Although primarily phytophagous, the larvae have been found attacking inactive stages of various insects including prepupal larvae of the sugar-beet webworm, *Loxostege sticticalis* Linnaeus, and egg pods of the grasshoppers *Camnula pellucida* Scudder and *Melanoplus* spp. In captivity, cannibalism occurs if the larvae are overcrowded. Strickland (1935, pp. 521-524; 1939; 1942) discusses the biology of this species and reports the larval period as varying from 3 to 10 years and the number of larval instars as ranging from 10 to at least 24. Rearing studies conducted at the Saskatoon laboratory have shown pupation to occur in the field from July 11 to August 8, most commonly in late July. Under laboratory conditions the pupal period usually lasts from 2 to 3 weeks. The pupal chamber is an unlined, irregular, earthen cell, commonly subovate, measuring from 9 to 10 mm. by 18 to 22 mm.; usually it is formed within 3 inches of the soil surface.

In addition to the primary features of the *aeripennis* group, the most important characters for the identification of the larva of *Ludius aeripennis* are: Ninth abdominal segment (figs. 6, *d*; 7, *a, d*) without setae on central dorsal area and with broad, rounded "teeth" (*to*) on sides of dorsal plate, and abdominal mediotergites (*mtg*, fig. 6, *a, c*) with transverse branches of impressions on second to eighth segments reaching approximately one-third of distance from longitudinal branches to middorsal suture. In structure, the two subspecies are indistinguishable except by size. The typical *aeripennis* larva attains a length of 27 or 28 mm. and a width of 3.75 mm.; *destructor* rarely exceeds 22 mm. in length and 3 mm. in breadth. The eastern North American *appropinquans* (Randall) and the European *aeneus* (Linnaeus) are so similar that constant structural differences have not been found and separation is most readily made on the basis of distribution.

A detailed description of the mature larva of *L. aeripennis destructor* Brown is given on pages 19-29. A general description was published by the writer in 1935 and prior to that the larva was figured by Strickland (1926, p. 7, fig. 1).

Material used in study.—Sixteen examples of the typical *aeripennis* and 36 of the subspecies *destructor* were examined. This material included the cast skins of 7 reared specimens of the typical form and 6 of *destructor*. Reared adults were all identified by W. J. Brown, Ottawa, Ontario.

L. aeripennis aeripennis (Kirby): To avoid misidentification, at least one specimen was reared to the adult state from each of the four groups of material selected for use in the present study.

- 4; Stump Lake, Saskatchewan; May 20, 1935; 2 reared adults emerged May 1, 1936, and July 4, 1936; B. Rysstad. (C.N.C.)
- 5; Dawson Creek, British Columbia; July 1935; a reared adult emerged June 2, 1936; K. M. King. (C.N.C.)
- 5; Tacoma, Wash.; Sept. 26, 1934; 2 reared; M. W. Stone. (C.N.C.)
- 2; Kirkland, Wash.; Aug. 30, 1933; 2 reared; E. W. Jones. (U.S.N.M.)

L. aeripennis destructor Brown: During the past 10 years large numbers of larvae of this species have been examined. However, in the present study careful examination was limited to approximately 36 specimens. These were from Saskatchewan (26) and Alberta (10). Twenty-seven specimens were collected from areas where the typical *aeripennis* has never been found. The other 9 were from the Peace River area of Alberta, but identification was confirmed by rearing. All this material is in the Canadian national collection. Separate collections for which associated reared adults are available are listed below.

- 20; Swift Current, Saskatchewan; June 1935; 4 reared adults emerged Aug. 27, 1935, May 4, 1936, and 2 on May 21, 1936; R. Glen and V. L. Berg.
- 4; Beaverlodge, Alberta; July 1935; 1 reared adult emerged Aug. 17, 1935; K. M. King.
- 5; Clairmont, Alberta; July 1935; 1 reared to adult Mar. 30, 1936; K. M. King.

LUDIUS APPROPINQUANS (Randall) (?)

Elater appropinquans RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 5, 1838.

Ludius appropinquans (Randall), BROWN, Canadian Ent., vol. 67, pp. 130-131, 1935.

According to Brown (1935b, p. 131) this eastern North American species is distributed from central Manitoba and Wisconsin to the Atlantic coast. It is a forest species, occurring in the decomposing litter and under the bark of decayed coniferous logs and stumps.

The larvae are believed to be predaceous, feeding upon the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), being reported in a personal communication from R. F. Morris, Fredericton, New Brunswick.

In structure, the larva is identical with that of *L. aeripennis* and *L. aeneus* and separation is most readily secured through differences in distribution.

Material used in study.—Three larvae were examined. These were not identified through rearing, but were collected from litter under spruce in Sunbury County, New Brunswick. On the basis of structure these larvae belong unquestionably to the *aeripennis* group and the locality fits the known distribution of *appropinquans*. (Canadian national collection.)

LUDIUS PRUININUS (Horn)

FIGURES 13, *i*; 15, *a-c*

Corymbites pruininus HORN, Trans. Amer. Ent. Soc., vol. 3, p. 320, 1871.

Ludius pruinosus SCHWARZ, in Wytsman's Genera Insectorum, pp. 46, 226, 1907.

Corymbites noxius HYSLOP, Proc. Biol. Soc. Washington, vol. 27, p. 69, 1914.

Ludius pruininus (Horn), BROWN, Canadian Ent., vol. 67, p. 135, 1935.

The range of *pruininus* is indicated by Brown (1935b, p. 135) as bounded by Nebraska, California, and the Okanagan Valley of British Columbia. Lane (1925, p. 91; 1935, pp. 529-530) states that the distribution is governed by rainfall, the species occurring only on the semiarid sagebrush and bunchgrass regions which have an annual rainfall not exceeding 15 inches. This species is a serious pest of grain crops in the dry-farming districts of the area, but disappears in a few seasons from fields brought under irrigation. According to Hyslop (1915a, p. 13) and Lane (1931, p. 5) pupation may occur during the third year of larval life or from one to several years later, probably depending upon environmental conditions. The pupal chamber is constructed from 4 to 8 inches below the soil surface, usually in the hard soil just below the tillage line.

The larva is figured by Hyslop (1915a, p. 12, fig. 4), but no detailed description or comparison with closely related species is given.

Ludius pruininus is readily distinguished from *L. aeripennis* by possessing the following characters of the ninth abdominal segment (fig. 15, *a*): Four setae on central dorsal area; narrower and sharper "teeth" (*to*) on sides of dorsum; and paramedial impressions (*pm*) on dorsal plate usually distinct posteriorly, although coming close together and sometimes lying within a shallow median concavity.

Largest larva examined measured 23 mm. in length and 3.25 mm. in breadth without being fully distended. Furcal pits (prothorax) deeper than in *aeripennis*. Transverse branch of impressions on first eight abdominal segments usually shorter than in *aeripennis*. Urogomphi (*ur*, fig. 15, *a*; fig. 15, *b*, *c*) and prongs exceedingly variable in size, shape, and presence of tubercles, but usually as described below. Inner prong (*ipr*) slightly more slender than outer prong, projecting caudad and slightly mediad, with rather long, sharp, upturned, horny tip; prominent tubercle (sometimes absent) on posteroventral aspect, usually not very conspicuous from dorsal view; several small setae and 2 or 3 prominent hairs ventrally, 1 of which arises near base of tubercle; 1 prominent seta on posterodorsal surface, anterad to tubercle. Outer prong (*opr*) projecting dorsad, usually slightly caudad, with sharp, horny tip inclining backward (sometimes straight); conspicuous sharp, horny, setiferous tubercle (*tub*) laterally just below base of prong; 1 prominent seta on anterolateral aspect, several smaller setae around distal part of prong. Caudal notch (*cn*) highly variable, usually U-shaped, about as long as broad, narrower posteriorly; sometimes much wider than long, or subovate and longer than wide.

Material used in study.—In all, 27 specimens were examined, including the larval exuviae of 4 specimens reared to adults. All material was from the State of Washington and is stored in the Canadian national collection and the U. S. National Museum. The reared adults were identified by both M. C. Lane, Walla Walla, Wash., and W. J. Brown, Ottawa, Ontario. Whole larvae from Ritzville were examined, but these were collected on a different occasion from those that were reared to adults as listed below.

4; Ritzville, Wash.; all reared to adults; M. C. Lane. (U.S.N.M.: Ritzville Laboratory No. 20, subnumbers -41A5, -42E2, -42F1, -42F6.)

LUDIUS AENEUS (Linnaeus)

Elater aeneus LINNAEUS, Systema Naturae, ed. 10, vol. 1, p. 406, 1758.

Selatosomus aeneus (Linnaeus), STEPHENS, Illustrations of British entomology, Mandibulata, vol. 3, p. 268, 1830.

Ludius aeneus (Linnaeus), BOISDUVAL and LACORDAIRE, Faune Entomologique des Environs de Paris, vol. 1, p. 666, 1835.

Aphotistus aeneus (Linnaeus), KIRBY, in Richardson's Fauna Boreali-Americana, vol. 4, p. 149, 1837.

Corymbites (*Selatosomus*) *aeneus* (Linnaeus), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 370, 1927.

This common species is widely distributed in temperate and central Europe and in western Siberia. The larvae inhabit the soil of meadows, forests, and cultivated fields, preference being shown for drier locations and soils of a sandy texture. European literature is replete with references to *aeneus* as a major pest of cereals, root crops, potatoes, Jerusalem artichokes, legumes, tobacco, forest seedlings, and buddings in fruit nurseries. Ghilarov (1937, p. 636) considers this species to be almost purely phytophagous. However, Chrzanowski (1931) has observed the larvae to attack weakened or inactive insects, including moulting larvae of their own species.

The mature larva attains a length of 25 mm. when fully distended. It has been described from Denmark by Schiodte (1870, pp. 519-520) and Henriksen (1911, pp. 262-263), from France by Perris (1877, p. 180), and from Germany by Altum (1878, p. 74), Beling (1883, pp. 281-283; 1884, p. 204), and Horst (1922, pp. 32-35). *L. aeneus* is readily separated from the larva of *latus* through lack of setae on the central dorsal area of the ninth abdominal segment. However, structural characters fail to distinguish the larvae of *aeneus* and the American species *aeripennis* and *appropinquans*, and identification must be based primarily upon distribution. When compared with *aeripennis destructor*, the majority of the *aeneus* larvae examined had the anterior margin of the caudal notch straighter, the urogomphi slightly broader in relation to the width of the caudal notch, and the outer prongs of the urogomphi more nearly at right angles to the inner prongs. But all these characters failed when tested in an adequate series of specimens.

Both Schiodte and Henriksen refer to the musculature being visible through the integument. This was evident on very few of the specimens examined in the present study and is believed to be an atypical condition probably resulting from desiccation or action of the preserving medium.

Material used in study.—Including some specimens that were available to K. L. Henriksen at the time he described this species, 22 larvae were examined. The material was collected in Finland (2), Denmark (8), Germany (8), and Italy (4). Reared adults and larval exuviae of reared specimens were not available. However, there is every reason to believe that the material used is definitely *Corymbites* (*Selatosomus*) *aeneus* (Linnaeus), as recognized by European entomologists, and is the larva referred to by that name in current entomological literature. The specimens examined are at present in the Canadian national collection (6), the U. S. National Museum (9), the British Museum (3), and the private collection of Dr. van Emden (4).

LUDIUS LATUS (Fabricius)

FIGURE 15, *d-f*

Elater latus FABRICIUS, *Systema Eleutheratorum*, vol. 2, p. 232, 1801.

Ludius latus (Fabricius), BOISDUVAL and LACORDAIRE, *Faune Entomologique des Environs de Paris*, vol. 1, p. 667, 1835.

Diacanthus latus (Fabricius), GERMAR, *Zeitschr. für die Ent.*, vol. 4, p. 77, 1843.

Corymbites (Selatosomus) latus (Fabricius), SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 370, 1927.

This species is a well-known pest from France to the Far Eastern area of Siberia. Crops attacked include cereals, vegetables, tobacco, chufa (*Cyperus esculentus* Linnaeus) and rubber-producing plants. In general, *latus* appears to inhabit typical "steppe" and "forest-steppe" areas. However, the preferred native habitat appears to be unknown. Regnier (1921) observed the species to be more dangerous in recently cleared land in France, but Beï-Bienko (1936) found relatively few larvae in virgin soil in the Orenburg district of western Siberia. Russian writers are in general agreement that *latus* is most abundant in abandoned fields, especially in land overgrown with *Agropyron*, *Artemisia*, and *Bromus*, and least abundant in fields that recently have been in clean fallow. Pilyugina (1937) found infestations of this species to be more severe on unirrigated fields than on irrigated tracts, and Semenov (1931) reports infestations to be heavier on the higher parts of tobacco fields. Thus, it would appear that *latus* prefers dry locations. Masaitis (1929) reports pupation as occurring at a depth of from 3 to 6 inches below the soil surface.

The larva has been described at length by Perris (1877, pp. 177-179), who failed to find differences from the larva of *aeneus*; Masaitis (1931) compared *latus* and *spretus*; and Rambousek (1928) referred briefly to *latus* in his key, but did not make comparisons with closely related species. Znamensky (1926, 1927) separates *latus* and *aeneus* in his illustrated keys, *latus* usually being dark reddish yellow and bearing well-defined tubercles ventrad to bases of urogomphal prongs, *aeneus* usually pale yellow and bearing small, indefinite tubercles ventrad to bases of urogomphal prongs.

Larvae examined in the present study measured up to 24 mm. in length and 3.0 mm. in width. The larva is very similar to that of *aeripennis* and *aeneus*, but, on the basis of the material at hand, differs in possessing the following characters: 2 setae on the central dorsal area of the ninth abdominal segment (fig. 15, *f*); transverse branches of the impressions on the first 8 abdominal segments slightly longer

than in *aeripennis destructor* (fig. 6, *a*, *c*) and on the ninth abdominal segment continuing clearly across the dorsum; subnasale worn on specimens examined, but giving indications of about 12 denticles on the serrate ridge. The material examined showed no distinct color differences from *aeneus*. Somewhat larger tubercles, as indicated by Znamensky, undoubtedly occur in specimens entirely free from erosion, but this character is believed to be very variable and should be used only to supplement the characters given above.

Material used in study.—Three larvae were examined. All were collected at Chuchkova, Moscow District, Russia, 1936, and were identified by M. Ghilarov. It is not known if the identification was supported by rearing. (U. S. National Museum collection.)

* * *

THE LUDIUS INFLATUS GROUP

FIGURES 13, *f*, *h*; 16, *a*

KEY TO SPECIES

- I. Transverse branches of impressions on the mediotergites of second to eighth abdominal segments reaching from one-eighth to one-sixth of the distance from longitudinal branches to mediodorsal suture; western North America.....*glaucus* (Germar) (p. 50)
- Transverse branches of impressions reaching from one-fifth to one-fourth of distance to dorsal suture; eastern North America.....
.....*inflatus* (Say) (?) (p. 55)

Knowledge of this group is based upon the larva of *glaucus* (Germar) and specimens from Urbana, Ill., which are probably *inflatus* (Say). Both species are soil inhabiting; their larvae have been confused and commonly referred to in the economic literature under the one name, *inflatus*.

This group is very closely allied to the *aeripennis* group, differing as follows: caudal notch subcircular or subovate; urogomphi and prongs relatively longer and more slender, bearing larger toothlike tubercles; ninth abdominal segment with 2 or 3 sharp "teeth" on lateral margins of dorsum, without setae on central dorsal area, and distance between pleural area and caudal notch equal to one-fifth to one-fourth length of segment exclusive of urogomphi; 3 lateroepicranial setae on each gena, arranged as 1 pair with an unpaired hair farther ventrad; without definite impressions on mediotergites of mesothorax and metathorax.

LUDIUS GLAUCUS (Germar)

FIGURES 13, *f, h*; 16, *a*

Diacanthus glaucus GERMAR, Zeitschr. für die Ent., vol. 4, p. 76, 1843.

Hadromorphus similissimus MOTSCHULSKY, Bull. Soc. Moscou, vol. 32, p. 374, 1859.

Ludius glaucus (Germar), BROWN, Canadian Ent., vol. 68, p. 135, 1936.

The distribution of this western species is indicated by Brown (1936c, p. 135) as extending from Utah to California and north to southern Alberta and the Okanagan Valley of British Columbia. The author has found the larvae in grain fields in southwestern Alberta and along the foothills of the Rocky Mountains as far north as Calgary. Essig (1926, p. 394, "*inflatus*") reports the species in Arizona and New Mexico. Under the name of *inflatus* Say, the larva has been recorded as an important pest in Washington, Oregon, Idaho, and Montana. The crops most frequently injured are wheat, corn, and potatoes. Lane (1925, p. 91) reports that the species inhabits areas where the annual rainfall exceeds 15 inches, and Hyslop (1915a, p. 10) describes the typical native habitat as one of bunchgrass (*Agropyron spicatum*) and June grass (*Poa secunda*) but lacking in sagebrush.

According to Hyslop (1915a, p. 11), the normal larval period is 3 years, pupation occurring in late June and early July. However, a specimen collected in May and reared by the writer did not pupate until August. The oval pupal cell measured 13 mm. by 6 mm. The transformation to the adult state is completed within 2 or 3 weeks and the beetles overwinter in their pupal chambers.

Distribution and slight differences in sculpture serve for the distinguishing of the larvae of *glaucus* and the closely related *inflatus*.

Description of "mature" larva.—Length 16 mm., greatest breadth 2.6 mm. on fourth and fifth abdominal segments. A fully distended larva measured 18.5 mm. Body robust; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about three-fourths greatest body width. Dorsum pale yellow (pale "yellow ocher," Ridgway, 1912) to very light brown; venter slightly paler. Dorsum bearing fine punctures, increasing in abundance on the more posterior segments.

Head subquadrangular with arcuate sides, flattened above and below.

Frontoclypeal region with posterior part extending backward to or almost to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting

of transverse ridge, anteriorly convex; serrate, when uneroded, with about 7 subequal short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 2 prominent setae and 2 to 4 minute setae.

Epicranial plates sparsely and finely punctulate. Dorsal sulci shallow, each bearing 5 setae subequally spaced, the most anterior seta being very long, the next seta minute and sometimes wanting, the 3 most posterior setae small. Ventral sulci bearing row of 7 to 10 setae, usually about 2 to 4 conspicuous. Three large lateroepicranial setae arranged as a dorsal pair and an unpaired ventral seta, usually with 1 or more small or minute setae caudad to unpaired hair. Eye spot black, well defined, ovate or circular; surrounded by 3 setae, rarely with an additional extremely minute seta. Postgenal areas expanded mesad, but always rather widely separated; glabrous.

Gula short, relatively wide; glabrous.

Antennae with first joint weakly clavate, two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; one-half length of basal joint; 1 or 2 pores; a few small "sensory" pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-half as long as second joint and one-quarter to one-third as wide; 4 setae on apex.

Mandibles of moderate length, robust; about three-fifths to five-sevenths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts only about three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-lateroventral aspect, sometimes also 1 or 2 smaller hairs. Galea with basal joint subcylindrical, slightly shorter than terminal joint; without setae; 2 or 3 faint pores. Terminal segment narrower than basal segment, outer margin longer than inner margin, with 7 to 9 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; distally on mesoventral surface with group of 4 or 5 small pores and 1 relatively large and 1 smaller seta. Second segment wider than long; as long as first joint and about as wide; without setae; with 4 or 5 pores. Third joint wider than long; about one-half length of second seg-

ment; 2 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment as long as wide or slightly longer than wide; about as long as third joint; 1 minute seta near middorsal aspect. Postmentum with 1 long seta near each corner, few minute pores scattered over surface. First prementum with 3 to 5 large setae just caudad to base of each palpus, forming transverse row of 6 to 10 hairs. Labial palpi with basal segment cylindrical, one-half length of first prementum, as long as wide, without setae, bearing up to 7 pores; terminal segment shorter than basal joint and about one-half as wide, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites with scattered small shallow pits; anteriorly with 7 to 9 setae (on each side of median dorsal suture) in transverse row, usually arranged as follows: the 2 most medial setae always paired, the next 1 or 2 setae unpaired, then a group of 3 setae and finally 1 unpaired seta considerably farther laterad; posteriorly with 5 to 8 (usually 6 or 7) setae in transverse row arranged as 3 pairs subequally spaced, or as 2 pairs with a group of 3 setae between, sometimes with 1 additional small seta between each pair and slightly farther caudad; glabrous elsewhere. Episternum with 1 large and 2 small setae. Epimeron bearing 1 prominent seta and 1 to 3 small or minute setae. Presternal area consisting of 4 sclerites as follows: a small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, each striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 5 minute setae or pegs on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate; impressions indistinct, reduced to short row of small pale pits. Anterior part of each mediotergite with 1 seta, near lateral margin; 1 pair large setae farther caudad along lateral margin; posterior part of mediotergite with 2 pairs conspicuous setae and sometimes 1 or 2 additional small hairs; minute setae sometimes observable in some of pits. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Each episternum bearing up to 11 spinelike setae (usually 6 or 7). Eusternum with transverse row of 4 to 6 fine setae. Mesothoracic spiracle subequal in size to spiracles in abdomen.

Legs subequal in length. Coxa with up to 50 (usually 25 to 45) spinelike setae on anterior aspect; 4 or 5 stout setae and a few scattered fine hairs on posterior surface. Trochanter less than one-half

length of coxa; with 6 to 9 spinelike setae on medioanterior surface; 6 to 9 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 6 to 10 spinelike setae on medioanterior surface; 5 or 6 spinelike setae and 1 slender seta on posterior surface; 1, rarely 2, long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 3 to 5 spinelike setae and one slender seta on medioanterior surface; 3 to 5 spinelike setae on posterior surface. Ungula, when uneroded, about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites with small, shallow punctures, becoming denser from first to eighth segment; impressions not conspicuous, very small on first segment; transverse branch slightly sinuate, on second to eighth segments extending one-eighth to one-sixth distance from longitudinal branch to middorsal suture; longitudinal branch of impression extending from one-half to three-fifths distance from transverse branch to posterior transverse row of setae, longer on more posterior segments. Anterior part of mediotergite without setae, except for an extremely minute seta sometimes observable near medial end of impression; 2 semipaired setae along lateral margin, just anterad to middle of segment; posterior part of mediotergite, with transverse row of 6 setae, arranged as 3 pairs, sometimes 1 or 2 very small setae close to the paired hairs. Laterotergite I extending length of segment; with 1 to 3 setae. Spiracular sclerite small, subovate, becoming longer and narrower in the more posterior segments; in the eighth segment very little wider than spiracle, but about 3 times as long; always in anterior half of segment. Spiracles subequal in length, in extreme posterior part of spiracular sclerite. Pleurite large, subovate or subtriangular, with 3 or 4 setae. Sternum of 1 piece, subquadrate, narrower opposite pleurite; with 4 faint longitudinal impressions, a lateral pair and a paramedial pair which meet posteriorly; bearing up to 12 setae, mostly near margins of sclerite.

Ninth abdominal segment (fig. 16, *a*), exclusive of urogomphi, as long as, or slightly shorter than, eighth abdominal segment and four-fifths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about three-fifths to two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; densely punctulate; 4 faint longitudinal

impressions, 2 laterally and a paramedial pair which converge posteriorly sometimes meeting in a median groove; without setae except at lateral margins, which are slightly raised and carinate, bearing 3 small, sharp "teeth" (*to*) (the most anterior very small, most posterior largest), each with 1 long bristle; a fourth "tooth" is situated farther caudad and ventrad; transverse impression wanting. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 16 to 28 setae on each side, some issuing from small sclerotized tubercles; lateral aspect usually moderately densely punctulate. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth to one-fourth total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except at anterior ends where small ovate pleurites. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite with from 8 to 14 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 16, *a*; fig. 13, *f*) well developed, separate, bifid; directed dorsocaudad; prongs well developed, subequal; urogomphi and prongs long and relatively slender. Inner prong (*ipr*) directed mesocaudad and slightly dorsad, terminating in sharp, upturned horny point; prominent, sharp, toothlike tubercle (*tub*) on ventro-caudolateral aspect, halfway along prong; sometimes an additional small tubercle ventrally near base of prong; 3 large setae, one ventrally at base of prong, 1 from inner aspect and 1 from upper aspect of base of prominent tubercle; usually 2 or 3 smaller setae issuing from prong near base of large tubercle. Outer prong (*opr*) somewhat corniform; directed dorsad, and usually slightly caudad with sharp tip turned posteriorly; large, horny tubercle (*tub*) with sharp upturned point situated laterally just below base of prong; usually with 3 large setae, 1 from anterolateral aspect, about halfway along prong, 2 from near upper aspect of base of tubercle; several small, fine setae scattered over distal half of prong, most abundant on posterior surface at point where prong distinctly becomes narrower. Undivided part of urogomphus about as long as divided portion; without setae except as noted above. Caudal notch (*cn*) large, shape variable, but usually subcircular; about as broad as long, somewhat narrowed posteriorly.

Tenth abdominal segment with 1 whorl (sometimes 2 whorls) of 10 fine setae; anal aperture linear and median.

Material used in study.—Twenty-two specimens were examined, 3 from Alberta and 19 (U. S. National Museum collection) from the State of Washington. The latter were received through the courtesy

of M. C. Lane, who obtained larvae from mated adults that he personally identified. The parent adults apparently were not retained.

3; Bradshaw, Alberta; May 28, 1942; 1 reared to adult Aug. 10; R. Glen (C.N.C.).

LUDIUS INFLATUS (Say) (?)

Elater inflatus SAY, Ann. Lyc. Nat. Hist. New York, p. 258, 1825.—LECONTE, Complete writings of Thomas Say, vol. 1, p. 392, 1859.

Elater metallicus SAY, Ann. Lyc. Nat. Hist. New York, p. 258, 1825.

Ludius inflatus (Say), BROWN, Canadian Ent., vol. 68, p. 134, 1936.

According to Brown (1936c, p. 135), *inflatus* is an eastern species, adults being known from South Carolina to southern Quebec and Ontario and as far west as Indiana.

Blatchley (1910, p. 767) found the adults in low open woods, but the larval habitat has not been described. However, larvae believed to be of this species were taken from soil in the "University Woods," an elm-maple forest located about 5 miles northeast of the campus of the University of Illinois. Describing the "University Woods," Weese (1924, p. 8) states, "The drainage is poor, so that in wet seasons the soil becomes saturated with moisture, and water may stand for some time in the Spring in depressions even in the higher parts of the woods. The soil is yellow-gray silt loam, an upland timber soil." This area has an average annual rainfall believed to be in excess of 35 inches.

These facts suggest that *inflatus* is primarily a forest or parkland species, probably restricted to well-watered soils. There are no published records of *inflatus* (*sensu stricto*) causing injury to cultivated plants.

Structurally the larva of *inflatus* is very similar to that of *glaucus*. On the basis of the rather inadequate material that was available for study, the two species may be separated as follows: in *inflatus* the punctuation is slightly less conspicuous, and the transverse branches of impressions on the abdominal mediotergites are slightly longer. In *glaucus* the transverse branch of each impression reaches from one-eighth to one-sixth the distance from the longitudinal branch to the mediodorsal suture, in *inflatus* from one-fifth to one-fourth that distance.

To determine the constancy and reliability of the above differences it will be necessary to obtain additional material, the greatest need being for *inflatus* larvae identified through rearing. At present, the principal reliance in the identification of these species must be upon geographic distribution.

Material used in study.—Only two specimens, from the “University Woods,” Urbana, Ill., were used in the present study. These were not associated with reared adults and were identified primarily through their eastern locality. On the basis of adult characters, Brown (1936c) indicates that *L. inflatus* (Say) is the only eastern species closely related to *L. glaucus* (Germar). The larvae examined are deposited in the Canadian national collection.

* * *

THE LUDIUS EDWARDSI GROUP

FIGURES 13, *e*; 16, *c*, *d*, *f*

KEY TO SPECIES

1. From North America..... 2
 From Siberia.....*spretus* (Mannerheim) (p. 63)
2. Urogomphal prongs (fig. 16, *c*) relatively straight, with short, curved tips; full-grown larvae exceed 20 mm. in length; in forest areas....
 *Ludius cruciatus festivus* (LeConte) (?) (p. 62)
- Urogomphal prongs (fig. 16, *d*) curved, with long, curved tips; full-grown larvae do not exceed 16 mm. in length; in prairie and open parklands*sexualis* Brown (?) (p. 57)

On the basis of larval characters, three species have been included in this group, namely, the Siberian *spretus* (Mannerheim), the North American *sexualis* Brown, and an unidentified species.

It is possible that the unidentified larvae are *Ludius cruciatus festivus* (LeConte), which occurs in wooded areas of western North America. On the basis of adult characters, Brown (1935a, pp. 1-3) places the European *cruciatus* (Linnaeus) and its American subspecies in the *cruciatus* group, which is closely allied to the *edwardsi* group. Whether this distinction is supported by larval characters cannot be determined without accurately identified larval material. However, the larvae of both *spretus* and *sexualis* inhabit the soil of prairie and parklands whereas the larvae here regarded as *cruciatus festivus* are found in forest soil.

Larvae of the *edwardsi* group are known to injure cultivated crops, especially cereals.

This group is characterized as follows: The body is widest in the region between the mesothorax and the third abdominal segment, the ninth abdominal segment is subquadrate (fig. 16, *f*), the urogomphi resemble grappling hooks (fig. 16, *c*, *d*), and the pleurites in the anterior abdominal segments are less than three-fourths as long as the

sternum. Very close allies are found in the *semivittatus* group for which very inadequate larval material is at hand.

The larvae of the *edwardsi* group are bright yellow. Caudal notch large, broadly U-shaped or transversely ovate. Urogomphi short, thick, with subequal prongs terminating in rather long, sharp, horny tips giving appearance of grappling hooks; tip of outer prong curving backward and downward; no prominent tubercles on prongs. Ninth abdominal segment with 1 to 3 small, blunt tubercles or "teeth" on each lateral margin of dorsum; 4 or more setae on central dorsal area; and distance between pleurite and caudal notch about one-tenth to one-eighth of total length of segment, exclusive of urogomphi. Nasale typically of 1 large median tooth with a small denticle on each side of base, lateral denticles sometimes lacking. Frons truncate posteriorly, extending to or almost to foramen magnum. One "sensory" appendix on second segment of antenna. Eyes usually present, but often small and inconspicuous. Basal segment of labial palpi with 1 seta ventrally. Gula short and wide. Mandible somewhat concave dorsally on distal half. Presternum of prothorax divided into 3 or 4 sclerites. Mesothorax and metathorax with indistinct impressions on mediotergites; and each episternum bearing spinelike setae varying in number to a maximum of 5; mediotergites of second to eighth abdominal segments with transverse branch of impressions extremely short, almost wanting; and with most conspicuous setae arranged in pairs, each pair consisting of 1 short and 1 long seta. Pleurite on first abdominal segment less than three-fourths as long as sternum.

LUDIUS SEXUALIS Brown (?)

FIGURES 13, e; 16, d, f

Ludius sexualis BROWN, Canadian Ent., vol. 67, pp. 7-8, 1935.

Brown records this species from Saskatchewan, Alberta, and Wyoming, and states that it is evidently closely allied to the Siberian *spretus* (Mannerheim) and to the mountain-dwelling American *morulus* LeConte.

Larvae of *sexualis* have not been identified through rearing, but larval specimens have been collected at Saskatoon, Saskatchewan, the locality of the paratypes used by Brown in his description of this species, and these larvae bear obvious resemblance to Masaitis' (1931) figures and description of the larva of *Ludius spretus* (Mannerheim). Since there are no other unidentified larvae of *Ludius* occurring in the Saskatoon district with which these specimens might be confused, it is believed that their identity is quite reliably established.

Ludius sexualis is evidently a plains species. In native situations it is associated with prairie grasses, especially with mixed grass and silverberry (*Elaeagnus*) and to a lesser degree with the grassy margins of snowberry (*Symphoricarpos*) thickets. It persists for many years after such areas have been brought under cultivation. The species has been found in some abundance in a few old brome-grass fields which originally contained large areas of snowberry. Larvae have been taken at depths ranging from near the soil surface to 22 inches. King (1928, p. 705, "*Ludius* (?) sp.") lists *sexualis* among the wireworms of lesser economic importance in Saskatchewan.

The larva strongly resembles that of a much larger unidentified species (possibly *cruciatus festivus* LeConte), from which it may be distinguished by size, the urogomphi (fig. 16, *c*, *d*), and the habitat.

Description of "mature" larva.—Length 16 mm., when fully distended; greatest breadth 1.6 mm. None of the specimens examined were larger. Segments usually subequal in width, sometimes wider in region of mesothorax, metathorax, and first to third abdominal segments. Body moderately robust; with moderately large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about four-fifths greatest body width. Dorsum pale yellow or light brown (near "cinnamon-buff," Ridgway, 1912); mouthparts and prongs of urogomphi darker, head and prothorax sometimes slightly darker; venter slightly paler. Dorsum slightly rugose; scattered minute, shallow pits usually observable on some segments.

Head subquadrangular with strongly arcuate sides; somewhat flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale consisting of large median tooth with a fine lateral projection on each side near base; lateral projections usually eroded away, giving nasale unidentate appearance. Subnasale indefinite and variable; usually without denticles; sometimes a few minute, sharp denticles arising from ventral surface of nasale almost halfway up median tooth, arranged in irregular transverse row. Paranasal lobes produced beyond nasale, each bearing 3 to 5 setae (1 or 2 small).

Epicranial plates with sparse, fine, inconspicuous punctures. Dorsal sulci shallow, each with 5 setae subequally spaced, the most anterior seta being long, others small. Ventral sulci bearing row of 5 to 7 setae, usually 2 to 5 conspicuous. Lateroepicranial setae include dorsal and ventral pairs (usually 1 large and 1 small seta in each pair) with 1

small seta anterad to dorsal pair and 2 or 3 minute setae in slight longitudinal depression posterad to ventral pair. Eye spot black; usually small and somewhat diffuse; ovate or circular; surrounded by 4 setae, sometimes 1 additional minute seta between eye spot and lateroepicranial setae. Postgenal areas expanded mesad, but well separated; glabrous.

Gula short, relatively wide; glabrous.

Antennae with first joint clavate, nearly as wide as long; without setae; 2 or 3 small pores. Second joint subcylindrical, about as wide as long; three-fifths length of basal joint; 1 or 2 pores, a few small pegs and setae borne distally, 1 laterad to, and almost as long as, "sensory" appendix; 1 medium-sized, conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, barely half as long as second joint and one-third as wide; 4 setae on apex.

Mandibles of moderate length, robust; two-thirds as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with long, shallow, dorsal groove; inner aspect sharp, convex ventrally, excavate dorsally.

Ventral mouthparts about three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 to 6 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, slightly shorter than terminal joint, usually without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, 7 to 9 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment slightly wider than long; distally on mesoventral surface with group of 2 or 3 small pores and 2 setae. Second joint distinctly wider than long; slightly shorter than first joint; without setae; 3 or 4 pores. Third joint wider than long; at least two-thirds length of second joint; 2 pores ventrally; distally, 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment as long as wide; about as long as third joint and at least one-half as wide; without setae; 1 pore. Postmentum with 1 long seta at each corner and 1 minute seta short distance caudad to each long anterior hair; few minute pores scattered over surface, 1 larger pore just anterad to each long anterior hair. First prementum with 1 large seta and sometimes also 1 smaller seta just caudad to base of each palpus. Labial palpi with basal joint about one-half length of first prementum, usually longer than wide, 1 small seta and 2 to 5 pores on ventral surface; terminal joint small, from one-half to two-thirds length and

about one-half width of basal joint; without setae; usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; only very slightly wider posteriorly; slightly wider than long. Tergites minutely punctulate; anteriorly with about 7 setae (on each side of median dorsal suture) in transverse row, usually arranged as 3 pairs (1 short and 1 long seta in each pair) and 1 unpaired seta farther laterad; posteriorly with 6 setae in transverse row arranged as 3 pairs (1 short and 1 long seta in each pair); usually 1 or 2 minute unpaired setae near center of sclerite. Episternum usually with 1 large and 1 or 2 smaller setae near center and a few minute hairs near margin adjacent to presternum. Epimeron with 1 or 2 minute setae. Presternal area consisting of 4 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, bearing 2 fine setae anteriorly; 2 large subtriangular lateral sclerites striate on anterolateral aspect, with 1 stout bristle laterad to center and a diagonal row of 3 or 4 minute setae on anteromedial aspect; and a very narrow, median, anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous or weakly sclerotized.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; impressions indistinct. Anterior part of each mediotergite with transverse row of 4 small unpaired setae, the most lateral seta largest; posterior part of each mediotergite with transverse row of 4 to 6 setae, arranged as 2 pairs (1 short and 1 long seta in each pair) and sometimes 1 or 2 unpaired setae; 1 pair of setae on lateral aspect of mediotergite; additional minute setae sometimes observable in punctures, especially in anterior part of sclerite. Anterior laterotergite subtriangular, almost one-half as large as subovate posterior laterotergite. Episternum bearing up to 5 (usually 3 or 4) spinelike setae. Mesothoracic spiracles about equal in size to or very slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa usually with 20 to 30 spinelike setae on anterior aspect, mostly in 2 or 3 oblique rows; 1 or 2 stout setae and a few small, scattered hairs on posterior surface. Trochanter with 5 to 7 spinelike setae on medioanterior surface; 3 to 6 such setae and 1 or 2 fine setae scattered on posterior surface; 2 well-developed setae on medial surface. Femur usually with 4 to 8 spinelike setae on medioanterior surface; 2 to 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 2 or 3 spinelike setae on medioanterior surface; 2 or

3 spinelike setae on posterior surface. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; first and second segments sometimes widest, but usually very little difference in width. Mediotergites with a few small, shallow, indistinct pits; transverse branches of impressions very short and indistinct, curving slightly backward; longitudinal branch of impression only a faint groove extending approximately one-half distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with transverse row usually of 4 unpaired setae arranged as follows: most lateral seta largest, situated below impression; 1 at end of transverse branch of impression; 1 halfway between transverse branch and median dorsal suture; 1 tiny seta near dorsal suture; sometimes a few additional minute setae. Posterior part of mediotergite with transverse row of about 10 setae (fewer in first segment), 6 most conspicuous setae arranged as 3 pairs (1 short and 1 long seta in each pair), 1 small seta between pairs, 1 or 2 minute setae farther mediad than most medial pair, sometimes 1 minute seta laterad to most lateral pair. Lateral part of mediotergite with 1 or 2 small setae short distance caudad to most lateral seta in anterior row. Laterotergite I extending length of segment; bearing 4 to 6 setae, only 1 conspicuous. Spiracles subequal; borne in posterior part of small, ovate spiracular sclerite which is approximately twice length of spiracle and situated in anterior half of segment. Pleurite large, subtriangular; bearing 3 or 4 setae (only 1 long) on posterior half; definitely largest in first segment and smallest in eighth. Sternum of 1 piece, subquadrate, narrower posteriorly; usually bearing from 10 to 16 setae, mostly near lateral margins.

Ninth abdominal segment (fig. 16, *f*) exclusive of urogomphi, slightly shorter than eighth abdominal segment and almost as wide; three-fourths to four-fifths as long as wide; sides subparallel. Dorsum strongly convex; with minute, sparse punctures; 4 faint longitudinal impressions, 2 laterally and a paramedian subparallel pair; central area with 4 conspicuous setae (2 most posterior longer) and usually 2 to 6 small setae; lateral margins not well defined, almost lacking anteriorly, bearing 1 or 2 small, blunt, setiferous tubercles ("teeth") posteriorly and 1 or 2 unpaired setae farther forward; transverse impression short and very faint, almost wanting. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 20 to 30 setae on each side, nearly all in posterior half of segment. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-tenth

total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except for small ovate pleurite at anterior ends. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with from 10 to 15 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 16, *f*; fig. 16, *d*), separate, bifid, short, robust; prongs subequal, dark and horny, resembling grappling hooks. Inner prong (*ipr*) directed mediocaudad in horizontal plane, with sharp, horny point turning upward; small horny tubercle on caudolateral surface; usually 3 or 4 long setae and as many smaller setae arising from outer surface of prong; sometimes a few fine setae on inner aspect. Outer prong (*opr*) projected dorsad or caudodorsad and usually slightly mesad with long, sharp, horny point curving backward and usually slightly inward and downward; small tubercle laterally just at base of prong; 2 or 3 large setae, 1 issuing from anterior or anterolateral aspect, almost halfway up prong, 1 or 2 from base of tubercle; up to 10 smaller setae scattered over prong. Undivided part of urogomphus very short; thick; usually with a few fine short setae scattered over mesal, ventral, and lateral surfaces.

Caudal notch (*cn*) large, U-shaped or transversely subovate, wider than long, somewhat narrowed posteriorly by tips of inner prongs.

Tenth abdominal segment with a proximal whorl of about 20 fine setae and a distal whorl of 10 such hairs; anal aperture linear and median.

Material used in study.—Twelve specimens were examined. All were collected at Saskatoon, Saskatchewan, from native sod and cultivated fields. The species has not been reared and identification is based upon field association of adults and larvae and upon other evidence presented in the introductory paragraphs of the discussion of this species. (Canadian national collection.)

LUDIUS CRUCIATUS FESTIVUS (LeConte) (?)

FIGURE 16, *c*

Corymbites festivus LECONTE, Reports of explorations and surveys . . . from the Mississippi River to the Pacific Ocean, vol. 12, pt. 3, No. 1, p. 46, 1857.
Ludius cruciatus festivus (LeConte), BROWN, Canadian Ent., vol. 67, p. 3, 1935.

Unidentified larvae, obviously closely allied to *sexualis* Brown, were found in soil at Stump Lake in northern Saskatchewan. This collection was made in 1934 in a field which reportedly had been part of a spruce forest until 1926. These larvae were found together with

larvae of *Ludius aeripennis* (Kirby) and *Limonium pectoralis* LeConte and might have contributed to the damage to grain crops that was reported in connection with the infestation.

The material available for examination was limited to four specimens that were not in good condition, having died and desiccated before being placed in preservative. In all specimens the mouthparts were noticeably eroded and it is possible that erosion had shortened the tips of the urogomphal prongs and the unguulae of the legs.

The larvae attain a length in excess of 20 mm., probably exceeding 25 mm. when fully distended; greatest breadth exceeding 3 mm. Prongs of urogomphi (fig. 16, *c*) relatively straight through most of length, the converging tips being distinctly farther apart than in *sexualis* (fig. 16, *d*). Nasale much as in *sexualis*, but lateral projections usually present. Subnasale worn in specimens at hand, but appears to have 4 or 5 short, forward-projecting denticles. Coxae of prothoracic legs each bear up to 40 spinelike setae on anterior surface.

The material examined is stored in the Canadian national collection.

LUDIUS SPRETUS (Mannerheim)

Corymbites spretus MANNERHEIM, Bull. Soc. Moscou, vol. 25, p. 285, 1852.

Corymbites (Selatosomus) spretus (Mannerheim), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 381, 1927.

According to Masaitis (1931) this species is widely distributed over Siberia, being particularly abundant in the central and western areas. Pospelova (1937) includes *spretus* among the predominant wireworms in the steppe and forest steppe regions of western Siberia. It is a well-known pest (Beř-Bienko, 1928; Masaitis, 1929, 1931; Pospelova, 1937) of root and grain crops, becoming most abundant in fields covered with *Agropyron repens*. Masaitis (1929) reports that pupation occurs during the latter half of July, at from 3 to 6 inches below the soil surface. The pupal period lasts 3 to 4 weeks.

Larvae of this species have not been available for examination in the present study. Knowledge of their morphology is limited to the description and figures given by Masaitis (1931). Since Masaitis' study was restricted to a comparison of the larvae of *spretus* and *Ludius latus* (Fabricius) it is not possible, at present, to give structural characters separating *spretus* and its closer allies, and primary reliance must still be upon geographical distribution.

The following is a summary of the most significant characters of the ninth abdominal segment, as described by Masaitis: Segment subquadrangular, only slightly narrowed posteriorly; dorsum convex, finely wrinkled, bearing 6 setae arranged as 3 transverse rows of 2

setae each; 1 to 3 tubercles on each lateral margin of dorsum, placed close together and located toward the posterior end of segment; urogomphal prongs of equal size, with sclerotized tubercles on the ventral side at the point where the prongs diverge.

* * *

LUDIUS MELANCHOLICUS (Fabricius)

- Elater melancholicus* FABRICIUS, *Systema Entomologiae*, Suppl., p. 130, 1798.
Diacanthus melancholicus (Fabricius), GERMAR, *Zeitschr. für die Ent.*, vol. 4, p. 80, 1843.
Ludius melancholicus (Fabricius), GEBLER, *Bull. Soc. Moscou*, vol. 20, p. 425, 1847.
Corymbites melancholicus (Fabricius), BOSE, *Die Käfer Deutschlands von Valentin Gutfleisch*, p. 362, 1859.
Selatosomus melancholicus (Fabricius), MOTSCHULSKY, in *Schrenck's Reisen und Forschungen im Amur-Lande*, vol. 2, p. 109, 1860.
Corymbites (Selatosomus) melancholicus (Fabricius), SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 378, 1927.

Xambeu (1912, p. 142) described the larva of this European species under the name *Diacanthus melancholicus* Olivier. The larvae are said to be carnivorous and to inhabit the soil under well-sunken stones, or under the dung of large ruminants, at altitudes up to 1,800 meters. Pupation occurs in July, with the adults appearing in August.

Specimens were not available for examination in the present study and Xambeu's description is not adequate for the accurate identification of the species or for determination of its relationships.

The most important characters given by Xambeu may be summarized as follows: Length 25 mm.; breadth 2.5 to 3.0 mm. Nasale unidentate. Prothorax densely punctate; abdominal segments sparsely punctate, ornamented laterally with 2 groups of setae. Ninth abdominal segment with dorsal plate strongly punctate and bearing 3 "teeth" on each side. Caudal notch horseshoe-shaped. Urogomphi bifid, prongs darkened, arched, and converging; 1 tubercle at base of each prong.

* * *

LUDIUS AMPLICOLLIS (Germar)

- Diacanthus amplicolis* GERMAR, *Zeitschr. für die Ent.*, vol. 4, p. 80, 1843.
Corymbites amplicolis (Germar), CANDEZE, *Monographie des elatérides*, vol. 4, p. 155, 1863.
Corymbites (Selatosomus) amplicolis (Germar), SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 373, 1927.

The larva of this European species is described by Xambeu (1912, pp. 144-148), who reports it as abundant in mountains at 800 to 1,200

meters. The larva is stated to be carnivorous, especially on ants, and frequents the nests of *Formica coespitum* Linnaeus. Xamheu states that, in contrast to all other species of *Ludius*, *ampliocollis* completes its life cycle in 1 year, the eggs hatching at the end of summer, the larvae that emerge pupating the following May.

Xamheu's description is inadequate both for the accurate identification of the species and for determining its relationships. Specimens were not available for examination in the present study.

The following is a summary of the most important larval characters given by Xamheu: Length 16 to 18 mm.; breadth 2 to 3 mm. Young larvae yellowish; older specimens reddish, venter yellowish. Nasale dark and tridentate. Eyes present. Prothorax finely punctured. First 8 abdominal segments punctate, each bearing a posterior transverse row of 6 or 7 reddish setae. Spiracles in anterior half of each segment. Ninth abdominal segment long, narrow, strongly punctate. Caudal notch large. Urogomphi bifid, outer prong long and arched. Anal opening linear.

* * *

THE LUDIUS SEMIVITTATUS GROUP

FIGURE 16, *b, e*

The material at hand is entirely inadequate for the establishment of group characters, only a single specimen labeled "*Ludius fuscus* Lec. (or *semivittatus* Say)" being available.

Brown (1936a, pp. 11-17) has shown that the adults of *semivittatus* (Say) and its allies have been much confused in collections. He erected the species *deceptor* Brown and *funereus* Brown for specimens that he believed Dr. Van Dyke and others had misidentified as *fuscus* (LeConte), the latter being excluded from the *semivittatus* group. In addition, *blanditus* Brown and *sexguttatus* Brown were created for species commonly confused with *semivittatus* (Say). Thus, it is impossible to state which species, as recognized by Brown, is represented by a specimen labeled "*Ludius fuscus* Lec. (or *semivittatus* Say)," but in all probability it is one of the western species included by Brown in his *semivittatus* group.

This larva reveals a close relationship to the *edwardsi* group. As with the *edwardsi* larvae, the most striking feature is the horny urogomphal prongs (fig. 16, *e*) shaped as grappling hooks. The two groups may be separated as follows: In *semivittatus*, the pleurites

of the first abdominal segment (*pl*, fig. 16, *b*) are virtually as long as the sternum, in *edwardsi* less than three-fourths as long; in *semivittatus*, there are 3 lateroepicranial setae, arranged as a dorsal pair and 1 unpaired ventral hair; in *edwardsi* there are 2 pairs..

On the basis of larval characters, this species might have been retained with the *edwardsi* group. The decision to place it in a separate group was based primarily on the fact that it differed in characters that were constant in the other species.

LUDIUS SEMIVITTATUS (Say) (?)

FIGURE 16, *b*, *e*

Elater semivittatus SAY, Journ. Acad. Nat. Sci. Philadelphia, vol. 3, p. 174, 1823.—LECONTE, Complete writings of Thomas Say, vol. 2, p. 113, 1859.

Ludius semivittatus (Say), BROWN, Canadian Ent., vol. 68, p. 13, 1936.

As stated above, this is the larva of *semivittatus* (Say) or of a closely allied western species. The single specimen upon which this study was made was collected at Walla Walla, Wash., but the range of the species cannot be stated with certainty. Nothing is known of the larval habits except that the available specimen was taken from an alfalfa field.

This larva strongly resembles that of *Ludius sexualis* Brown. Only the main differences from *sexualis* are described since the specimen is not in sufficiently good condition for an adequate detailed comparison.

Length about 15 mm. Nasale consisting of a large median tooth with a prominent lateral projection on each side near base; lateral denticles appear serrate anteriorly because subnasal sclerotization is closely joined with them. Subnasale consisting of transverse ridge, slightly convex ventrally, serrate, with 7 to 10 short, forward-projecting denticles (eroded condition of specimen prevents exact count). Epicranial plates with 3 lateroepicranial setae, arranged as 1 pair with an unpaired hair farther ventrad. Coxa of prothoracic leg with 40 spinelike setae on anterior surface. Pleurite of first abdominal segment (*pl*, fig. 16, *b*) nearly as long as sternum; on second and third segments, respectively, pleurites about three-fourths and one-half as long as sterna. Urogomphi (fig. 16, *e*) differing from *sexualis* as follows: inner prongs (*ipr*) somewhat stouter than outer prongs (*opr*), and with more pronounced tubercle (*tub*) on posterolateral aspect.

The specimen examined is deposited in the U. S. National Museum.

THE LUDIUS PROPOLA GROUP

FIGURES 13, *c*; 17

KEY TO SPECIES

1. Outer prongs of urogomphi (fig. 17, *d*, *e*) at least three times as long as inner prongs; Rocky Mountains and Pacific coast.....
 *pubicus* Brown (p. 74)
- Outer prongs of urogomphi (fig. 17, *a*, *f*, *g*) not more than twice as long as inner prongs; east of Rocky Mountain region..... 2
2. Inner prongs of urogomphi (*ipr*, fig. 17, *f*, *g*) twice as long as width at base; larva may exceed 16 mm. in length; eastern North America...
 *hieroglyphicus* (Say) (p. 73)
- Inner prongs of urogomphi (*ipr*, fig. 17, *a*) less than twice as long as wide; larva not exceeding 16 mm. in length; Atlantic coast to Rocky Mountains*propola propola* (LeConte) (p. 68)

Group characters are based on larvae of *propola* (LeConte), *pubicus* Brown, and *hieroglyphicus* (Say). All are North American species and believed to be forest inhabitants.

These larvae bear superficial resemblance to those of the *triundulatus* group, but are readily separated by the following characters: Outer urogomphal prong with sharp tip (fig. 17, *c-g*), antenna (fig. 17, *b*) with 1 "sensory" appendix, impressions shorter on abdominal mediotergites, and sternum undivided in first 5 abdominal segments.

Larvae of the *propola* group are bright yellow. Caudal notch large, subovate, U-shaped or approaching V-shaped. Urogomphi bifid, with outer prongs larger than inner prongs; tip of outer prongs sharp, inclining forward. Ninth abdominal segment without setae on central dorsal area; and with 3 prominent, blunt "teeth" on lateral margins of dorsum. Nasale unidentate, with 2 to 6 setae on each side of base, in sinuosities between nasale and paranasal lobes. Second joint of antenna bearing 1 "sensory" appendix. Eyes present. Basal joint of labial palpi with 1 small seta on ventral aspect. Gula short, but relatively wide. Frontoclypeal area bluntly rounded posteriorly. Mandible much as *aeripennis* type, with short, moderately deep dorsal groove. Presternum of prothorax divided into 3 sclerites. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of abdominal segments with prominent setae unpaired (at least not definitely paired), and transverse branch of impressions not exceeding four-fifths of the distance from longitudinal branch to middorsal suture. Sternum of 1 piece on first to eighth abdominal segments.

LUDIUS PROPOLA PROPOLA (LeConte)

FIGURES 13, *c*; 17, *a-c*

Corymbites propola LeConte, Trans. Amer. Philos. Soc., vol. 10, p. 437, 1853.
Corymbites furcifer LeConte, Trans. Amer. Philos. Soc., vol. 10, p. 438, 1853.
Ludius propola propola (LeConte), Brown, Canadian Ent., vol. 68, p. 184, 1936.

The taxonomy of this species and its nearest relatives has been revised by Brown (1936d). The typical *propola* is regarded as an eastern species which ranges from Maine and Nova Scotia to the Rocky Mountains, where it is replaced by the subspecies *columbianus* Brown.

The larva of only the typical form is known. All specimens were found in litter under poplar or spruce or mixed stands of these two trees. Pupation occurs in late July, with the adults developing in early August. One pupa was found inside of a small decayed twig and another within a cell in leafmold.

The larva resembles the larger *hieroglyphicus* (Say), from which it differs by having shorter and stouter urogomphi and prongs (fig. 17, *a, c*).

Description of "mature" larva.—Length 16 mm., fully distended; greatest breadth 2.0 mm. on fourth to sixth abdominal segments. Body robust; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum bright yellow (between "ochraceous buff" and "clay colour," Ridgway, 1912); head and urogomphi somewhat darker; venter paler. Dorsum slightly rugose, sparsely punctulate.

Head subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, usually bluntly rounded posteriorly. Two or three prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting of strongly sclerotized transverse ridge; serrate when uneroded, with 6 to 8 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 or 4 setae (1 or 2 small).

Epicranial plates sparsely and finely punctulate. Dorsal sulci wanting or practically so, but in usual region of each are 4 setae, subequally spaced, the most anterior seta being very long, others very small. Ventral sulci bearing row of 6 to 9 setae, usually 5 to 8 conspicuous. Two pairs of lateroepicranial setae (1 of each pair usually

short, sometimes lacking) and 2 unpaired setae farther dorsad, the more lateral of the unpaired setae is definitely more anterior than the paired hairs; 1 or 2 additional tiny setae sometimes present. Eye spot black, well defined, ovate or circular; surrounded by 3 or 4 prominent setae. Postgenal areas expanded mesad but always rather widely separated; glabrous.

Gula short; narrowed slightly by converging postoccipital sutures, but of good width; glabrous.

Antenna (fig. 17, *b*) with first joint weakly clavate, usually at least five-sixths as wide as long; without setae; 2 or 3 small pores. Second joint subcylindrical, as wide as long; one-half to three-fifths length of basal joint; 1 or 2 pores; a few small "sensory" pegs and setae borne distally; 1 large conical "sensory" appendix (*sap*) just ventrad to base of third joint. Terminal segment small, as long as second joint, but only one-quarter to one-third as wide; 4 or 5 setae on apex.

Mandibles of moderate length, robust; about five-sevenths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short, moderately deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts from two-thirds to three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large, only two-thirds as wide posteriorly as anteriorly; proxistipes and dististipes not distinct; usually 5 to 8 prominent setae on antero-lateroventral aspect. Galea 2-jointed; basal joint subcylindrical, rather indefinite, shorter than terminal joint, without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, with 2 to 4 pores on lateroventral aspect. Maxillary palpi with all joints subcylindrical. First joint twice as wide as long; distally on mesoventral surface with group of 2 or 3 small pores and 2 setae, 1 or 2 pores near midventral aspect. Second joint wider than long; as long as first joint or slightly longer and at least two-thirds as wide; without setae; with 1 or 2 pores. Third joint wider than long; about one-half length of second joint; bearing 2 pores ventrally; distally with whorl of 4 or 5 fine setae; sometimes also 1 or 2 small "sensory" pegs distally. Fourth joint longer than wide; longer than third joint; one pore laterally and sometimes 1 minute seta near middorsal aspect. Postmentum with 1 long seta at each corner, 1 smaller seta short distance anterad

to each long anterior hair, usually 2 or 3 small hairs along each side; few minute pores laterally. First prementum with 1 large and 2 smaller setae just caudad to base of each palpus, forming transverse row of 6 hairs. Labial palpi with basal joint about one-half length of first prementum, about as long as wide, 1 seta ventrally, 1 or 2 pores; terminal joint nearly as long as basal joint and one-half as wide, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; usually slightly wider than long. Tergites minutely punctulate; anteriorly with from 10 to 14 setae (on each side of median dorsal suture) in transverse row, usually 8 to 12 prominent, remainder small or minute, none definitely paired, all well removed from middorsal suture; posteriorly with 6 to 10 setae arranged transversely in irregular row, about 5 to 8 prominent, none definitely paired; sometimes 1 or more fine setae approximately midway between transverse rows, usually laterad to center of sclerite. Episternum with 1 large and 2 or 3 small setae. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: a small posterior median sclerite, anteriorly attenuate, with 2 fine short setae anteriorly; 2 large subtriangular lateral sclerites (usually joined anteriorly), striate on anterolateral aspect, with 1 stout seta laterad of center and a diagonal row of 3 or 4 minute "sensory" pegs or setae on anteromedial aspect. Eusternum small, membranous or weakly sclerotized; furcal pits each with 1 minute seta. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression reaching about one-fifth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from some of punctures. Posterior part of each mediotergite with from 5 to 9 unpaired setae in transverse row, about 5 to 7 prominent, remainder small or minute. Lateral part of mediotergite with 2 or 3 prominent setae, sometimes additional small or minute hairs. Anterior laterotergite subtriangular, one-half to two-thirds as large as subovate posterior laterotergite. Episternum bearing 1 or 2 fine setae but without spinelike setae. Eusternum with 2 conspicuous setae, sometimes additional minute setae. Mesothoracic spiracle small, usually slightly larger than spiracles in abdomen.

Legs subequal in length. Coxae of prothoracic legs with from 12 to 16 spinelike setae on anterior aspect, on mesothoracic and metathoracic legs with 16 to 20 such setae; 2 or 3 stout setae and a few

fine hairs scattered on posterior surface. Trochanter with 4 to 6 spine-like setae on medioanterior surface; 3 to 4 such setae and 1 fine seta scattered on posterior surface; 2, sometimes 3, well-developed setae on medial aspect. Femur usually with 6 to 9 spinelike setae on medioanterior surface; 2 or 3 spinelike setae and 1 or 2 slender setae on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 3 to 5 spinelike setae and 1 slender seta on medioanterior surface; 2 to 5 spinelike setae on posterior surface; usually 1 or 2 fine setae laterally. Ungula, when uneroded, about three-fifths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites with scattered small punctures; transverse branch of impression slightly sinuate, on second to eighth segments reaching from one-half to slightly over two-thirds distance from longitudinal branch to middorsal suture, shorter on first segment; longitudinal branch of impression extending from two-thirds to five-sixths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite without row of setae. Posteriorly on each mediotergite, transverse row of 5 to 8 prominent unpaired setae and usually 3 to 5 shorter setae placed between (and sometimes slightly caudad to) some of larger hairs. Usually 2 to 4 setae along margin of mediotergite, laterad to impression. Laterotergite I extending length of segment; with 4 or 5 setae. Spiracles small, subequal in all segments; spiracular sclerite small, subovate, in anterior half of segment, nearing middle of segment in posterior part of abdomen. Pleurite large, subovate, usually with 2 prominent setae, sometimes also 1 or 2 minute hairs. Sternum typically of 1 piece, subquadrate; with faint impressions near lateral aspects (only rarely are these impressions deepened or suture-like, separating off laterosternites on some of the more anterior segments); usually 6 to 8 prominent unpaired setae around margin of sclerite, sometimes also a few minute setae.

Ninth abdominal segment (fig. 17, *a*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; with a few small pits; 4 faint longitudinal impressions, 2 laterally and a short paramedian pair (in anterior part of plate) which converge posteriorly

but do not meet; without setae except at lateral margins, which are slightly raised and carinate, and bear 3 prominent blunt "teeth," each with a long bristle; transverse impression (*trim*) continues completely across segment. Tergite continues uninterrupted laterally and on posterior ventral surface; usually with from 10 to 16 unpaired setae on each side, some issuing from small sclerotized tubercles; anteriorly on lateral aspects with a few small punctures. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth of total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except at anterior ends where small ovate pleurite. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture, and posteriorly by tenth abdominal segment; each sclerite with from 6 to 9 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 17, *a*; fig. 17, *c*) separate, bifid; projecting caudad or dorsocaudad; inner prong usually about one-half size of outer prong. Inner prong (*ipr*) short, projected caudad and usually slightly dorsomedial, with sharp upturned tip; less than twice as long as wide; 2 large setae, 1 on caudolateral aspect, other ventrally at base of prong; usually a few minute hairs scattered on prong. Outer prong (*opr*) usually well developed; projecting caudodorsad, sometimes slightly laterad, terminating in sharp, horny point usually curving forward at tip; 2 large setae, 1 from anterolateral surface (usually in distal half of prong), other from lateral aspect of base of prong; several minute setae scattered over prong, the most noticeable usually on anteromesal surface near tip of prong. Undivided part of urogomphus with 1 to 3 setae on ventral aspect, usually 1 or 2 large.

Caudal notch (*cn*) large, U-shaped, sometimes with anterior margin slightly notched; longer than wide; usually only slightly narrowed posteriorly.

Tenth abdominal segment with whorl of 10 fine setae; sometimes additional minute setae in complete or partial whorl farther proximad; anal aperture linear and median.

Material used in study.—Examination was made of 15 specimens, including the larval exuviae of 2 specimens reared to maturity. Reared adults were identified by W. J. Brown, Ottawa. All specimens were collected in Saskatchewan at the following points: Saskatoon (4), Katepwa (1), Emma Lake (3), Round Lake (7). Unfortunately no whole larvae were collected at the same time and place as the specimens that were reared, but some were collected on different dates

from the identical spot at Saskatoon from which a reared specimen had previously been taken. Notes follow on reared adults and their associated exuviae.

- 1; Katepwa, Saskatchewan; Aug. 1, 1934; pupa and larval exuvium found together in pupal chamber; adult emerged by August 20; R. Glen. (C.N.C.)
- 1; Saskatoon, Saskatchewan; May 21, 1938; adult emerged July 24; R. Glen. (C.N.C.)
- 2; Arlington Heights, Mass.; (date collected not known); both specimens reared, No. 16393 emerging September 6, 1919, date of emergence of No. 16392 not known. (U.S.N.M.)

LUDIUS HIEROGLYPHICUS (Say)

FIGURE 17, *f, g*

- Elater hieroglyphicus* SAY, Trans. Amer. Philos. Soc., vol. 6, p. 172, 1839.—
LECONTE, Complete writings of Thomas Say, vol. 2, p. 607, 1859.
- Ludius bicinctus* CANDEZE, Mem. Soc. Roy. Sci. Liege, vol. 17, p. 173, 1863.
- Corymbites ctenicerus* GEMMINGER and HAROLD, Catalogus Coleopterorum, vol. 5, p. 1577, 1869.
- Ludius hieroglyphicus* (Say), BROWN, Canadian Ent., vol. 68, p. 181, 1936.

This eastern species is recorded by Brown (1936d, p. 182) from the northeastern United States and from Quebec to Manitoba in Canada.

Blatchley (1910, p. 767) reports taking the adults from trees and shrubs about the margins of lakes and marshes. Larvae believed to be of this species were collected from the decomposing litter under spruce in New Brunswick and Nova Scotia. These were observed by R. F. Morris, Dominion Entomological Laboratory, Fredericton, New Brunswick, to attack the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), during rearing studies.

In *hieroglyphicus*, the prongs of the urogomphi (fig. 17, *f, g*) are relatively slender, the inner prongs being at least twice as long as their greatest width; the outer prongs are nearly twice as long as the inner prongs and much thicker. The size of mature larvae is not known, but it is certain that they would exceed 16 mm. (the maximum length of *propola* larvae) and probably would exceed 20 mm. Each gena usually bears only 3 lateroepicranial setae with an additional hair farther dorsad and another farther anterad; 1 exuvium had 2 pairs of lateroepicranial setae. Antenna with first segment two-thirds as wide as long and about twice as long as second segment. Coxae of prothoracic legs bearing up to 19 spinelike setae on each anterior surface; each coxa of mesothoracic and metathoracic legs with up to 24 spinelike setae. On mediotergites of second to eighth abdomi-

nal segments the transverse branches of impressions reach from two-thirds to four-fifths distance from longitudinal branches to middorsal suture.

Material used in study.—The only material available was the larval exuviae of two reared specimens and two whole larvae that by comparison were believed similar. The reared adults were identified originally by R. H. van Zwaluwenburg and checked by W. J. Brown, of Ottawa.

LUDIUS PUDICUS Brown

FIGURE 17, *d, e*

Ludius pudicus BROWN, Canadian Ent., vol. 68, p. 183, 1936.

This western species is known to inhabit British Columbia, southwestern Alberta, and the State of Washington.

Nothing is known of the larval habits since the only specimens available for study were reared from eggs laid in captivity.

The larva is well characterized by its very large, corniform outer prongs of urogomphi (*opr*, fig. 17, *d, e*), which are at least 3 times as long as the inner prongs. The largest larva examined was 17 mm. long, but mature specimens might be larger. Each gena bears only 3 lateroepicranial setae, with an additional seta farther dorsad and another farther anterad. First segment of antenna two-thirds as wide as long and about 3 times as long as second segment. Coxae of prothoracic legs bearing up to 25 spinelike setae on each anterior surface; coxae of mesothoracic and metathoracic legs with up to 35 spinelike setae. On each mediotergite of second to eighth abdominal segments the transverse branch of impression reaches about one-half of the distance from the longitudinal branch to the middorsal suture.

Urogomphi (fig. 17, *d, e*) well developed. Inner prong (*ipr*) short, projecting caudodorsad and slightly mediad with sharp, horny tip curving upward and slightly forward; bearing 2 large setae, 1 ventrolaterally near base, other ventrally at base; a few minute hairs on prong. Outer prong (*opr*) corniform, very large and strong; about as long as undivided part of urogomphus and at least 3 times as long as inner prong; projecting caudodorsad and slightly laterad, with sharp horny tip curving forward; 2 prominent setae, 1 on anterolateral aspect about halfway along prong, other (longer) laterally at base of prong; several minute setae scattered over prong, the most noticeable on the anteromedial aspect in distal half of prong. Undivided part of urogomphus with 1 prominent seta and 1 or 2 minute setae, all on ventral surface.

Caudal notch (*cn*) large, U-shaped or V-shaped.

Material used in study.—Two larvae were examined. Both had been reared from eggs obtained from adults collected at Walla Walla, Wash., by H. P. Lanchester and identified by M. C. Lane of Walla Walla, but the adults were not retained. The specimens are the property of the U. S. National Museum. One specimen (Truck Crop No. 2762) was identified as *L. pudicus* Brown, but the other (Truck Crop No. 2761) was identified as *Ludius propola columbianus* Brown. On the basis of larval characters this specimen is believed to be of the same species as larva No. 2762 and most likely to be *L. pudicus* and not *L. propola columbianus*. The evidence in support of this conclusion may be summarized as follows: (1) the two larvae are morphologically indistinguishable, except in characters known to vary between individuals; (2) specimen No. 2761 is larger than any specimen of the typical *propola* (which has been reared at the Saskatoon Laboratory), but according to Brown (1936d), adults of *propola columbianus* are not larger than those of *propola propola*, whereas adults of *pudicus* are larger; (3) the larvae in question are definitely distinct from the larva of *propola propola*, whereas the writer has not been able to find diagnostic subspecific characters for other larval Elateridae (e.g., in *Ludius aeripennis*, *Ludius cupreus*, and examples in other genera); and (4) a misidentification of the adult could easily occur, since Brown (1936d) writes in his description of *L. pudicus* (p. 183), "Frequently the subbasal markings are not extended on the second interval (of the elytra) and the specimens then resemble *propola columbianus* in color."

* * *

THE LUDIUS TRIUNDULATUS GROUP

FIGURES 13, *g*; 14, *d*; 18

KEY TO SPECIES

- Outer prongs of urogomphi standing erect, forming an angle of approximately 90° with the undivided base of each urogomphus (fig. 18, *e*);
 Montana, Washington, British Columbia. *nebraskensis* (Bland) (?) (p. 81)
- Outer prongs of urogomphi projecting caudodorsad, forming an angle of approximately 130° with the undivided base of each urogomphus (fig. 18, *f*); coast to coast in Canada. *triundulatus* (Randall) (p. 76)

Knowledge of this group is based upon the larva of *triundulatus* (Randall) and upon a larva which is probably *nebraskensis* (Bland).

The closest relatives are found in the *propola* group from which distinction is secured through characters of the urogomphi (fig. 18,

e, f), antennae (fig. 18, *d*), sternum of the first 5 abdominal segments (fig. 18, *c*), and impressions on abdominal mediotergites (fig. 18, *b*).

Larvae of the *triundulatus* group are yellow or yellowish brown. Caudal notch large, U-shaped or V-shaped. Urogomphi bifid with subequal prongs; tip of outer prong smoothly rounded. Ninth abdominal segment without setae on central dorsal area, and with 3 "teeth" on lateral margins of dorsum. Nasale unidentate, with 2 setae on each side of base in sinuosities between nasale and paranasal lobes. Second joint of antenna bearing 2 "sensory" appendices. Basal joint of labial palpus without setae. Eyes present. Gula short, but relatively wide. Frontoclypeal area bluntly rounded posteriorly. Mandible with short, shallow, inconspicuous dorsal groove. Presternum of prothorax divided into 4 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired (at least not definitely paired); on mediotergites of second to fifth abdominal segments the transverse branches of impressions usually reach to or almost to the middorsal line. Sterna of first to fifth abdominal segments divided by deep lateral sutures, usually closed in segments 6 to 8.

LUDIUS TRIUNDULATUS (Randall)

FIGURES 13, *g*; 14, *d*; 18, *a-d, f, g*

Elater triundulatus RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 12, 1838.

Ludius triundulatus (Randall), BROWN, Canadian Ent., vol. 68, p. 106, 1936.

This species is known from the northeastern United States and from coast to coast in Canada.

The larvae have been found in abundance in damp litter and in very rotten wood under well-grown aspen poplar, but have also been collected from duff and decayed stumps under stands of willow, spruce, and pine. Larvae have been known to attack the cocoons of the European spruce sawfly,⁷ *Gilpinia hercyniae* (Hartig), and it is concluded that they are chiefly predatory. In western Canada, transformation to the adult state appears to occur normally in July, pupation usually occurring in the first half of the month, but adults have emerged in August from material collected in eastern Canada. Under laboratory conditions the pupal period lasts about 1 week.

In structure, the larva is very similar to that of *nebraskensis* (Bland) (?), differing only in characters of the ninth abdominal segment (fig. 18, *f, g*).

⁷ Information taken from labels accompanying larvae sent to the Saskatoon laboratory by R. E. Balch, Entomologist in Charge, Dominion Entomological Laboratory, Fredericton, N. B.

Description of "mature" larva.—Length 13 mm., fully distended; greatest breadth 1.4 mm. on fifth and sixth abdominal segments. Largest larva examined was 14 mm. long and 1.9 mm. wide. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum light brown or yellow brown (near "ochraceous tawny," Ridgway, 1912); head, prothorax, and urogomphi usually slightly darker; venter paler. Dorsum slightly rugose; with small shallow pits, rather inconspicuous.

Head subquadrangular with subparallel sides (very slightly arcuate); flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, bluntly rounded posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (fig. 18, *a*), unidentate, terminating sharply when uneroded. Subnasale (fig. 18, *a*) consisting of strongly sclerotized transverse ridge, slightly convex anteriorly; serrate when uneroded, with approximately 15 subequal, short, sharp, forward-projecting denticles (fewer in smaller specimens). Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates finely punctulate. Dorsal sulci shallow, each with 4 setae subequally spaced, the most anterior seta very long, others small. Ventral sulci bearing row of 5 to 7 setae, usually 2 to 4 conspicuous. On each gena, usually 3 lateroepicranial setae, 2 large with 1 smaller seta between; sometimes with 1 very small seta ventrocephalad to the more ventral of the 2 large hairs; 1 well-developed seta slightly laterad of anterior half of dorsal sulcus. Eye spot black, well defined, ovate or circular; surrounded by 5 unpaired setae, 3 well developed, 2 small. Postgenal areas expanded mesad, but well separated; glabrous.

Gula short, moderately wide; glabrous.

Antenna (fig. 18, *d*) with first segment weakly clavate, at least three-fourths as wide as long; without setae; 3 to 5 small pores. Second segment subcylindrical, as wide as long; one-half length of basal joint; 1 or 2 pores; a few minute setae or pegs borne distally; 1 medium-sized conical "sensory" appendix (*sap*) just ventrad to base of third segment and 1 smaller appendix farther ventrolaterad; in a few specimens there were 2 smaller appendices, making a total of 3 appendices on 1 antenna, and in 2 specimens the small appendix was lacking on 1 antenna but present on the other. Terminal segment as long as second joint, but only one-quarter as wide; 3 or 4 setae on apex.

Mandibles of moderate length, robust; at least three-fourths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half curving inward, pointed; outer surface convex with short, shallow, inconspicuous dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts about two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines separated by a distance equivalent to about one-half greatest width of single cardo. Stipites large, subrectangular, proxistipes and dististipes not distinct; usually 4 to 6 prominent setae on antero-lateroventral aspect. Galea 2-jointed; basal joint subcylindrical, not well defined, shorter than terminal joint, without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, 1 pore on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint wider than long; distally on mesoventral surface with group of 2 or 3 small pores and 1 or 2 setae. Second joint wider than long; about as long as first joint and almost as wide; without setae; 1 or 2 pores. Third joint almost as long as wide; about one-half length of second joint; 2 pores ventrally; distally with whorl of 4 small setae. Fourth joint slightly longer than wide; as long as or longer than third joint; without setae or pores. Postmentum with 1 long seta at each corner and 1 small or minute seta short distance anterad to each long anterior hair; 2 to 4 minute setae along each side. First prementum with 1 large and 1 small seta just caudad to base of each palpus, forming transverse row of 4 setae. Labial palpus with basal joint about one-half length of prementum, longer than wide, without setae, 2 pores; terminal joint narrow, but only slightly shorter than basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; about as wide as long. Tergites with minute punctures near middorsal suture, somewhat larger punctures laterally; anteriorly with 6 to 10 setae (on each side of median dorsal suture) in transverse row, usually 5 to 7 conspicuous, none definitely in pairs; posteriorly with 5 or 6 unpaired setae in transverse row, all well removed from middorsal suture; glabrous elsewhere. Episternum with 1 large seta and 3 or 4 small, fine hairs. Epimeron sometimes bearing 1 or 2 minute setae. Presternal area consisting of 4 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, posteriorly rounded, bearing 2 minute hairs anteriorly; 2 large subtriangular lateral sclerites striate on anterolateral aspect, with 1 stout

seta laterad to center and a row of 4 or 5 minute setae on antero-medial aspect; and a very narrow, median, anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate; transverse branches of impressions reaching about one-fourth to one-third distance from longitudinal branches to middorsal suture; longitudinal branches of impressions short, about one-half length of transverse branches. Anterior part of mediotergite without setae; posterior part with 4 or 5 conspicuous unpaired setae in transverse row, all well removed from median dorsal suture; lateral part with 2 large setae and sometimes 1 small seta, the most anterior hair being laterad to longitudinal branch of impression; minute setae sometimes observable in punctures. Anterior laterotergite subtriangular or subovate, one-half as large as subovate posterior laterotergite. Episternum without spinelike setae, 1 or 2 short, fine setae. Eusternum with 2 conspicuous setae, sometimes 2 to 4 minute setae. Mesothoracic spiracle slightly larger than spiracles in abdomen.

Legs subequal in length. Coxae of prothoracic legs with from 10 to 16 spinelike setae on each anterior aspect, on mesothoracic and metathoracic legs with 17 to 21 such setae, mostly in 1 row; 2 or 3 stout setae and a few fine hairs on posterior surface. Trochanter with 5 or 6 spinelike setae on medioanterior surface; 2 to 5 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 6 to 8 spinelike setae on medioanterior surface; 2 to 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 2 to 4 spinelike setae and 1 slender seta on medioanterior surface; 1 to 3 spinelike setae on posterior surface. Ungula, when uneroded, about three-fifths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 18, *b*) punctulate; transverse branches of impressions (*trim*) slightly sinuate, on second to fifth segments reaching to or nearly to median dorsal suture, on sixth and seventh segments usually slightly shorter, on eighth segment definitely not reaching dorsal suture, on first abdominal segment reaching only about one-half distance to dorsal suture (in a few specimens examined the transverse branches failed to reach the median dorsal suture in any segment); longitudinal branches of impressions (*loim*) extending obliquely backward at least two-thirds of distance

from transverse branch to posterior transverse row of setae and in some cases nearly the whole distance. Anterior part of mediotergite without row of setae. Posteriorly on each mediotergite, transverse row of 4 to 6 prominent unpaired setae and usually 1 to 3 short, fine setae placed between some of larger hairs. One prominent seta and sometimes also 1 small seta on margin of mediotergite laterad to impression. Laterotergite I extending length of segment; with 3 setae. Spiracles subequal; about in middle of segment just ventrad to most anterior seta on lateral aspect of mediotergite. Spiracular sclerite pale, subovate, wider than spiracle and 2 to 4 times as long. Pleurite (*pl*, fig. 18, *c*) large, subovate with 1 large and sometimes also 1 small seta near center. Sternum (*st*) subquadrate; in first 5 segments laterosternites (*lst*) separated off by well-defined sutures which are usually closed in sixth to eighth segments, sutures sometimes slightly open on sixth segment; usually about 6 unpaired setae around margin of sternum.

Ninth abdominal segment (fig. 18, *g*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; nearly as long as wide; posterior half tapering caudally, making width at anterior margin of caudal notch from three-fifths to two-thirds greatest width of segment. Dorsum slightly convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sparsely punctulate; 2 faint irregular impressions laterally; paramedian impressions inconspicuous and indefinite, sometimes meeting in a small, shallow, central, ovate depression; without setae except at lateral margins, which are raised and carinate, bearing 3 blunt "teeth," each with a long bristle; transverse impression (*trim*) continues completely across segment. Tergite continues uninterrupted laterally and on posterior ventral surface; usually with from 7 to 9 setae on each side, some issuing from small sclerotized tubercles; segment slightly expanded anteriorly on lateral aspects, usually with a few faint pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth of total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except for small ovate pleurite at anterior ends. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with 3 or 4 prominent setae and a few small setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 18, *g*; fig. 18, *f*) separate, bifid, projecting dorsocaudad; prongs subequal. Inner prong (*ipr*) projected caudad,

slightly dorsad, with short, sharp, upturned, horny tip; small tubercle on lateral aspect, slightly over half distance toward tip of prong; 2 prominent setae, 1 from base of tubercle and 1 from midventral surface of prong; sometimes 1 minute seta on ventral aspect anterad to large seta. Outer prong (*opr*) projecting caudodorsad (at an angle of about 45° to 50° with the inner prong) sometimes slightly laterad, terminating in a smooth, round, horny tip; small tubercle on midventral aspect of base; 2 prominent setae, 1 from base of tubercle and 1 projecting upward from upper surface of prong about two-thirds distance from base; usually a few minute setae on inner surface of prong toward tip. Undivided part of urogomphus with 1 large seta ventrally just anterad to junction of prongs.

Caudal notch (*cn*) large, U-shaped, anterior margin sometimes slightly notched.

Tenth abdominal segment with whorl of 10 fine setae; anal aperture linear and median.

Material used in study.—Fifty-one examples were examined, including the last larval exuviae of seven reared specimens. The reared adults were identified by W. J. Brown of Ottawa. All the material, including the adults, is stored in the Canadian national collection. All specimens examined were directly associated with reared examples.

43; Cypress Hills, Saskatchewan; June 3, 1934; specimen 16407-81N4(a) reared to adult, emerging in July 1934; R. Glen.

4; Cypress Hills, Saskatchewan; July 3, 1932; all reared to adults; H. McMahon and H. McDonald.

2; Elkwater Lake, Alberta; June 8, 1935; specimen 16407-81N5(a) emerged July 22, 1935; R. Glen.

1; Cascapedia River, Quebec; reared adult emerging Aug. 26, 1935; M. L. Prebble.

1; Golden Lake, Ontario; July 7, 1939; adult emerged Aug. 26, 1939; A. P. Arnason.

LUDIUS NEBRASKENSIS (Bland) (?)

FIGURE 18, *e*

Corymbites nebraskensis BLAND, Proc. Ent. Soc. Philadelphia, vol. 1, p. 355, 1863.

Ludius nebraskensis (Bland), BROWN, Canadian Ent., vol. 68, p. 106, 1936.

Brown (1936b, pp. 106-107) records this species from Montana and British Columbia. On the basis of adult characters, this author finds that *nebraskensis* (Bland) has been confused in collections with *triundulatus* (Randall) and *tigrinus* (Fall). The larva that has been considered as *nebraskensis* in the present study was reared from eggs obtained from adults collected in Washington State and identified by

M. C. Lane, of Walla Walla, Wash., as *L. triundulatus* (Randall). On the basis of larval characters it appears to be a distinct species from the one that has been reared from Quebec, Ontario, Saskatchewan, and Alberta, the reared adults of which have been identified by W. J. Brown as *triundulatus* (Randall). In a personal communication Mr. Lane states, "I should probably have designated one of Brown's species. It is the western variety, either *L. nebraskensis* (Bland) or *L. tigrinus* (Fall)." The larva of *L. tigrinus* (Fall) is not known, but *tigrinus* is a California species and thus less likely to be collected in Washington. Therefore, this larva is believed to be *nebraskensis* (Bland).

Nothing is known of the habits of the larva. Structurally, it may be distinguished from the larva of *triundulatus* by the following characters of the ninth abdominal segment: Segment relatively broad posteriorly and urogomphi more widely separated than in *triundulatus*; outer prongs of urogomphi (fig. 18, *e*) projecting dorsad, at right angles to the inner prongs and almost at right angles to the undivided parts of urogomphi; caudad notch more nearly V-shaped than U-shaped; and sharper "teeth" on lateral margins of dorsal plate.

This larva measured 8 mm. in length and 1 mm. in width, at the age of 6½ months. Since the adults of *nebraskensis* are larger than those of *triundulatus* it is expected that mature larvae should exceed 13 mm. in length. This specimen died and dried out before being preserved and so it was not entirely adequate for a complete comparative study. The specimen is deposited in the U. S. National Museum.

* * *

THE LUDIUS FALLAX GROUP

FIGURES 8, *d*; 19, 20

KEY TO SPECIES

- | | |
|--|---------------------------------------|
| 1. From Europe | 2 |
| From North America..... | 4 |
| 2. Dorsal plate of ninth abdominal segment with a transverse groove joining two longitudinal impressions ⁸ | <i>purpureus</i> (Poda) (p. 93) |
| Dorsal plate of ninth abdominal segment (fig. 20, <i>a</i>) without a transverse groove | 3 |
| 3. Posterior part of frons bluntly pointed (fig. 19, <i>b</i>); usually 5 "sensory" appendices on second segment of antenna (fig. 19, <i>d</i>)..... | <i>tessellatus</i> (Linnaeus) (p. 84) |
| Posterior part of frons broadly rounded; usually 2 "sensory" appendices on second segment of antenna (fig. 19, <i>e</i>) | <i>castaneus</i> (Linnaeus) (p. 89) |
| 4. Eastern North America..... | <i>medianus</i> (Germar) (p. 92) |
| Western North America..... | 5 |

⁸ Information taken from Beling (1883, p. 264, "*haematodes* Fab.").

5. Six "sensory" appendices on second segment of antenna.....
*viduus* Brown (?) (p. 90)
 Five "sensory" appendices on second segment of antenna.....
*bombycinus* (Germar) (p. 91)

Group characters are drawn from an examination of larval material of *tessellatus* (Linnaeus) and *castaneus* (Linnaeus) of Europe, and from *viduus* Brown, *bombycinus* (Germar), and *medianus* (Germar) of North America. On the strength of Beling's description (1883, pp. 262-265), the European *purpureus* (Poda) has been included in this group, but specimens could not be secured for study.

The larvae appear to inhabit soil, leaf litter, and decaying wood, and probably are chiefly predaceous. Blunck (1925) refers to the adults of *tessellatus*, *castaneus*, and *purpureus* as injuring buds and blossoms of fruit trees and the tender shoots of oak and pine, but there are no records of plant injury by the larvae.

On the basis of larval characters, the *fallax* group is not closely related to the other groups of *Ludius* that have been studied. Superficial resemblance is found in the larvae of the *propola* and *triundulatus* groups, but separation is readily achieved through color, nasale (fig. 19, *c*), the number of "sensory" appendices on the second segment of the antenna (fig. 19, *d*, *e*), and the urogomphi (fig. 20).

Larvae of the *tessellatus* group are brown to dark brown, sometimes with a superficial appearance of transverse bands of chestnut brown and paler color, but never prominently patterned. Caudal notch large, U-shaped. Urogomphi bifid, prongs subequal or inner prongs larger than outer prongs; tip of outer prong with very short, sharp point inclined inward. Ninth abdominal segment without setae on central dorsal area; and with 3 or 4 prominent, blunt "teeth" on lateral margins of dorsum. Nasale with tridentate tip, median denticle sharp and longer than lateral denticles which are truncate anteriorly; with 4 to 6 setae on each side of base of nasale in sinuosities between nasal and paranasal lobes. Second joint of antenna bearing from 2 to 6 "sensory" appendices. Basal joint of labial palpus without setae. Frontoclypeal area either bluntly pointed or broadly rounded posteriorly. Gula usually elongate and narrow, shorter in *castaneus*. Eyes present. Mandible with very short dorsal groove and with ventral margin of inner face of distal half continuing proximally to base of penicillus. Presternum of prothorax divided into 3 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired, and transverse branches of impressions reaching as far as three-fourths of the distance from the longitudinal branches to the middorsal line. Sternum of 1 piece on first to eighth abdominal segments.

LUDIUS TESSELLATUS (Linnaeus)⁹FIGURES 8, *d*; 19, *a, b, d, f, g*; 20, *a, b, e**Elatер tessellatus* LINNAEUS, Systema naturae, ed. 10, vol. 1, p. 406, 1758.*Elatер holosericeum* OLIVIER, Entomologie, vol. 2, No. 31, p. 27, 1790.*Ludius tessellatus* (Linnaeus), ESCHSCHOLTZ, in Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.*Prosternon holosericeum* (Olivier), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 152, 1834.*Corymbites tessellatus* (Linnaeus), GERMAR, Zeitschr. für die Ent., vol. 4, p. 62, 1843.*Prosternon tessellatum* (Linnaeus), DU BUYSSON, Faune Gallo-Rhénane, vol. 5, p. 84, 1894.*Prosternon tessellatum* (Linnaeus), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 399, 1927.

This species is known from northern and central Europe. The larva has been described from Denmark by Schiodte (1870, p. 518) and Henriksen (1911, pp. 267-268) and from Germany by Beling (1883, pp. 272-273).

The larvae inhabit both soil and decaying wood. The specimens used in the present study were collected from a beech stump, forest moss, and an old grass plot, and under stones. Schiodte records the larvae from meadow soil and Beling found larvae and pupae under the bark of rotten stumps of pine (*Pinus silvestris* Linnaeus). Xambeu (1912-13) states that the larvae feed upon xylophagous insects. That they are chiefly predaceous is further indicated by the total absence of records of plant damage by larvae of this species. Pupation occurs from late July to early August. The adults develop in August but spend the winter in their pupal cells.

Ludius tessellatus may be distinguished from its nearest European relatives by the following characters: Dorsum dark brown; 3 to 6 "sensory" appendices on the second joint of antenna (fig. 19, *d*); frons bluntly pointed posteriorly and terminating before reaching foramen magnum (fig. 19, *b*); and urogomphal prongs subequal or inner prongs only slightly longer than outer prongs (fig. 20, *a, b, e*). It is very similar in structure to the American species *medianus* (Germar), from which separation is best secured on the basis of distribution.

Description of "mature" larva.—Length 14 mm.; greatest breadth 2.5 mm. on fourth and fifth abdominal segments. Largest larva ex-

⁹ In certain parts of Europe the name *tessellatus* Linnaeus is still used in reference to larvae of *sjaelandicus* Müller, in spite of the fact that these are distinct species, the synonym of *sjaelandicus* Müller being *tessellatus* Fabricius, nec Linnaeus.

aminated was 17 mm. long and 3.0 mm. wide. Body robust, with large membranes on lateral aspect of thorax and abdomen; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum dark brown, each segment paler posteriorly, giving larva a superficial appearance of transverse bands of auburn shade (Ridgway, 1912) on paler background. Venter pale yellow, darker on under side of head and terminal part of ninth abdominal segment. Dorsum slightly rugose; minutely punctate, punctures usually more abundant on anterior half of segments.

Head (fig. 19, *a*) subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region (fig. 19, *b*) with posterior part extending backward almost to foramen magnum, but terminating definitely before reaching foramen; bluntly pointed posteriorly. Four to six prominent anterior nasosulcal setae (*nsa*) on each side of base of nasale. Nasale (*n*) well developed; tip tridentate, median denticle sharp (when uneroded) and longer than lateral denticles which are truncate anteriorly. Subnasale consisting of almost straight transverse ridge, finely serrate when uneroded. Paranasal lobes slightly produced beyond nasale, each bearing 4 setae (1 small).

Epicranial plates sparsely and finely punctulate. Dorsal sulci practically lacking, but with 4 setae in sulcal area; the most anterior seta very long, others small. Ventral sulci bearing row of about 7 setae, usually about 2 to 4 conspicuous. On each gena, usually 2 pairs of lateroepicranial setae (*lev*, *led*) with 1 unpaired seta nearer dorsal sulcus and 1 nearer setae surrounding eye. Eye spot (*e*) black, well defined, ovate or circular; surrounded by 4 unpaired setae. Postgenal areas expanded mesally, almost meeting anteriorly; glabrous.

Gula (*gu*, fig. 19, *f*) elongate, narrowed anteriorly; glabrous.

Antenna (*ant*, fig. 19, *a*; fig. 19, *d*) with first segment clavate, two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae or pegs borne distally; usually 5 (varying from 3 to 6) conical "sensory" appendices (*sap*) just ventrad to base of third segment. Terminal segment small, more than half as long as second segment but only one-quarter as wide; 4 or 5 setae on apex.

Mandibles of moderate length, robust; two-thirds to three-fourths as wide at base as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with very short dorsal groove; inner

face slightly excavate with small median carina, ventral margin of inner face sharp, slightly convex ventrally and continued proximally to base of penicillus, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts only three-fifths to two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines well separated mesally. Stipites large, subrectangular, noticeably wider anteriorly; proxistipes and dististipes not distinct; usually 5 or 6 prominent setae on antero-lateroventral aspect. Galea with basal segment subcylindrical, shorter than terminal joint, without setae or pores; terminal segment narrower than basal segment, outer margin longer than inner margin, 6 or 7 pores on ventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; distally on mesoventral surface with group of several small pores and 2 setae. Second joint as long as wide; as long as first segment and almost as wide; without setae; with 2 pores. Third joint wider than long; about one-half length of second segment; 2 or 3 pores ventrally; distally with 1 small seta on mesoventral aspect and 1 on lateral aspect. Fourth segment longer than wide; slightly longer than third joint; without setae or pores. Postmentum with 1 long seta at each posterior corner, 1 or 2 setae at anterior corners and 1 to 3 setae along lateral margins. First prementum with 3 or 4 setae just caudad to base of each palpus, forming transverse row of 6 to 8 setae. Labial palpi with basal joint at least one-half as long as prementum, slightly longer than wide, without setae, with 3 to 6 pores; terminal joint more than one-half length and about one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; wider than long. Tergites minutely punctulate; anteriorly with from 9 to 12 setae (on each side of median dorsal suture) in irregular transverse row, usually 6 to 9 conspicuous, others tiny, none definitely in pairs; posteriorly with 7 to 9 unpaired setae in transverse row; laterally with 1 or 2 setae between rows. Episternum with 2 or 3 large setae. Epimeron bearing 1 tiny seta. Pre-sternal area consisting of 3 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, with 2 tiny setae anteriorly; 2 large subtriangular lateral sclerites, usually joined anteriorly, striate on anterolateral aspect with 1 stout seta laterad to center and a row of 4 or 5 minute "sensory" structures on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate, punctures larger and more numerous anteriorly; transverse branches of impressions reaching from one-fourth to one-third distance from longitudinal impressions to middorsal suture; longitudinal branches of impressions short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from punctures; posterior part with transverse row of 6 to 9 unpaired setae; lateral part with 2 to 4 setae along lateral margin. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite, 1 seta ventrally. Episternum with 1 or 2 fine setae but without spinelike setae. Eusternum usually with 2 to 4 setae (only 2 conspicuous) in transverse row just anterior to coxae. Mesothoracic spiracle usually slightly larger than spiracles in abdomen.

Legs subequal in length, of good length. Coxa with up to 25 spine-like setae on anterior aspect, usually less on prothoracic legs; a few scattered fine setae on posterior surface. Trochanter with 6 or 7 spine-like setae on medioanterior surface; 3 to 5 such setae and a few fine setae on posterior surface; 2 well-developed setae on medial aspect. Femur as long as or longer than trochanter and about as thick; usually with 8 to 11 spine-like setae on medioanterior surface; 3 to 6 spine-like setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 4 spine-like setae and 1 slender seta on medioanterior surface; 3 or 4 spine-like setae on posterior surface. Ungula, when uneroded, at least three-fourths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; third to sixth segments widest; all segments wider than thick. Mediotergites (fig. 19, *g*) with small punctures, larger and more numerous in anterior half of segment; transverse branches of impressions (*trim*) slightly sinuate; length variable, on second to eighth segments reaching from one-half to three-fourths distance from longitudinal branch to middorsal suture (sometimes a faint impression runs farther mediad, almost to dorsal suture), on first abdominal segment reaching about one-half of distance to middorsal suture; longitudinal branches of impressions (*loim*) extending back to or almost to posterior transverse row of setae. Anterior part of each mediotergite without setae, except for a few minute hairs in some of punctures. Posterior part of each mediotergite with 5 to 9 conspicuous unpaired setae and a few smaller hairs, together forming an irregular transverse row. Two to four setae on margin of mediotergite laterad

to impression. Laterotergite I extending length of segment; with 3 setae. Spiracles slightly larger in first abdominal segment; in anterior half of segment, nearer to middle of sclerite in the more posterior segments. Spiracular sclerite small, subovate or subcircular. Pleurite large, subovate; with 2 or 3 setae (1 large). Sternum subquadrate; of 1 piece; 4 faint impressions, anterior pair meeting medially; bearing from 6 to 12 setae, mostly around margins of sclerite.

Ninth abdominal segment (fig. 20, *a, b*) exclusive of urogomphi, slightly longer than eighth abdominal segment and five-sixths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about three-fifths greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; punctulate, punctures small; 4 longitudinal impressions, 2 laterally (*lim*) from both sides of which short short impressed lines extend, and a short paramedian pair (*pim*) which converge posteriorly but do not meet; without setae except at lateral margins which are raised and carinate, bearing 3 prominent blunt "teeth," each with a long seta; transverse impression (*trim*) continues completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 12 to 18 setae on each side, some issuing from small sclerotized tubercles; 10 to 15 conspicuous punctures anteriorly on lateral aspect of segment. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-fifth of total length of segment, exclusive of urogomphi. Pleural area (*pl*) large, consisting of transversely striated membrane. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with from 6 to 9 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 20, *a, b*; fig. 20, *e*) separate, bifid; projecting prongs subequal or inner prong slightly longer. Inner prong (*ipr*) large; projecting caudad and slightly dorsomedial, with sharp upturned tip; 2 long setae, 1 laterally arising from a strongly margined socket and 1 halfway along ventral aspect. Outer prong (*opr*) usually slightly shorter than inner prong, projecting dorso-caudad and slightly laterad, with short horny tip (often absent due to erosion) curving anteromesad; 2 large setae, 1 ventrally at base of prong and 1 arising from anterior face of prong; sometimes a few fine, short setae around distal half of prong. Undivided part of uro-

gomphus with 1 large seta ventrally, just anterad to base of inner prong.

Caudal notch (*cn*) moderately large, U-shaped; usually not quite as wide as long, slightly narrower posteriorly.

Tenth abdominal segment (10, fig. 20, *b*) with whorl of 10 fine setae; usually 2 or 3 smaller setae on anterior aspect; anal aperture linear and median.

Material used in study.—Twenty-five specimens were examined. These were collected from Germany (21), Finland (3), and Denmark (1). The larvae are believed to be reliably named but reared adults were not available for confirmation. The material studied is deposited in the Canadian national collection, the U. S. National Museum, and van Emden's collection.

LUDIUS CASTANEUS (Linnaeus)

FIGURES 19, *c, e*; 20, *c*

Elater castaneus LINNAEUS, *Systema naturae*, ed. 10, vol. 1, p. 405, 1758.

Ludius castaneus (Linnaeus), ESCHSCHOLTZ, in Thon, *Entomologisches Archiv*, vol. 2, p. 34, 1829.

Corymbites castaneus (Linnaeus), LATREILLE, *Ann. Soc. Ent. France*, vol. 3, p. 150, 1834.

Corymbites (Anostirus) castaneus (Linnaeus), SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 364, 1927.

The larva of this European species has been described from Denmark by Schiodte (1870, p. 521) and Henriksen (1911, pp. 265-266) and referred to by Beling (1884, p. 205).

The larval habitat includes both soil and decaying wood. One of the specimens used in the present study was taken from a stump. Schiodte records the larvae as inhabiting forest meadows, and Henriksen states (translation): "mainly in sunny clay slopes, but also found in beech stumps." The species is not referred to in the economic literature. This suggests that the larvae are probably chiefly predaceous, as are those of the closely related *tessellatus* (Linnaeus).

In structure, the larva is very similar to that of *tessellatus* (Linnaeus), but may be readily distinguished by the following characters: Only 2 "sensory" appendices on the second antennal segment (*sap*, fig. 19, *e*); frons broadly rounded posteriorly; only 3 lateroepicranial setae, arranged as a dorsal pair with an unpaired hair farther ventrad; gula shorter than in *tessellatus*; and ninth abdominal segment with a deep median crease (*cr*, fig. 20, *c*) just in front of the caudal notch. Henriksen (1911, p. 266) records larvae attaining a length of 21 mm.,

but the largest specimen available for use in the present study measured only 12.5 mm.

It is possible that *castaneus* belongs to a distinct but closely related "species group," since in the characters of frons, gula, and antennae it departs from the general pattern found in *tessellatus*, *viduus*, *bombycinus*, and *medianus*.

Material used in study.—Three examples were examined, including the last larval exuvium of a reared specimen the adult of which was made available to the writer. Neither of the two whole larvae was collected at the same time as the reared specimen, but all three were from Denmark. The larvae examined are deposited in the U. S. National Museum. Notes on the reared specimen follow:

1; Holte, Denmark; Sept. 1, 1895; A. Ditlevsen. (R.V.A.C.)

LUDIUS VIDUUS Brown (?)

Ludius viduus BROWN, Canadian Ent., vol. 68, p. 103, 1936.

Brown (1936b, pp. 103-104) shows this species to be widely distributed over the southern part of British Columbia where it has been found together with *bombycinus* (Germar). The larva described below was collected under a stone on a hillside bearing conifers.

The larva of *viduus* differs from that of *tessellatus* (Linnaeus) in being of paler color, especially on first to sixth abdominal segments, in possessing more setae on thorax and abdomen and more spinelike setae on the legs, and in having the inner prongs of urogomphi twice as long as the outer prongs. It is much more closely related to *bombycinus* (Germar), from which it differs in antennal characters.

Length 17 mm.; greatest breadth 3.0 mm., on fourth and fifth abdominal segments. Only one specimen was available for examination and its relative maturity is unknown.

Dorsum transversely banded with chestnut brown and paler brown, anterior part of each segment darker; first to sixth abdominal segments palest.

Antenna with second segment slightly more than one-half as wide as long and bearing 6 conical "sensory" appendices just ventrad to base of third segment.

Each tergite of prothorax with an irregular anterior transverse row of 20 to 25 setae, a posterior transverse row of 10 to 14 setae, and 2 setae along lateral margin. Each mediotergite of mesothorax and metathorax with posterior transverse row of 12 or 13 setae and 6 to 8 setae near lateral margin. Each mediotergite on first to eighth abdominal segments with irregular posterior transverse row of 15 to

20 unpaired setae, and 5 to 9 setae near lateral margin. Laterotergite I bearing 4 to 7 setae. Pleurite with 3 to 5 setae.

Coxa with up to 30 spinelike setae on anterior aspect. Trochanter with 8 to 10 spinelike setae on medioanterior surface, 7 to 9 such setae on posterior surface. Femur with 12 or 13 spinelike setae on medioanterior surface, 6 or 7 spinelike setae on posterior aspect. Tibiotarsus with 6 to 8 spinelike setae on medioanterior surface and 5 to 8 such setae on posterior surface. Ungula, when uneroded, as long as tibiotarsus.

On ninth abdominal segment, distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-eighth of total length of segment, exclusive of urogomphi.

Urogomphi as figured for *bombycinus* (Germar) (fig. 20, *d, f*). Inner prong of urogomphus large, twice as long as outer prong; directed dorsocaudad, terminating in sharp, upturned point; with 2 prominent setae, 1 on lateral aspect, the other on midventral area. Outer prong short, robust; directed dorso-caudolaterad, with short, horny tip turned mediad; with 2 large setae, 1 on anterior aspect, the other laterally at base of prong; a few fine, short hairs around distal half of prong. Undivided part of urogomphus with 1 large seta ventrally, just anterad to base of inner prong.

Caudal notch large, U-shaped, slightly longer than wide.

Tenth abdominal segment with about 20 fine setae in irregular whorl.

Material used in study.—Only one specimen was used. Three larvae of this type were collected from under a stone, along with two adults of this species, but two of the larvae died and disintegrated too badly for use in the study. Since the relationships of this species, based upon adult characters, agree with the evidence deduced from this larva, it is believed that the larva is reliably named. The material was taken at Kamloops, British Columbia, and the adults were identified by W. J. Brown, of Ottawa. The larva is deposited in the Canadian national collection.

LUDIUS BOMBYCINUS (Germar)

FIGURE 20, *d, f*

Diacanthus bombycinus GERMAR, Zeitschr. für die Ent., vol. 4, p. 70, 1843.

Ludius bombycinus (Germar), BROWN, Canadian Ent., vol. 68, p. 101, 1936.

This species is known from Oregon, Washington, British Columbia, and the mountainous southwest of Alberta. Nothing is known of

the larval habitat, the only specimens available being obtained from eggs laid in captivity.

The *bombycinus* larva is very closely allied to that of *viduus* Brown. In the very inadequate material available for study the only observed difference was in the antennae. On the second antennal segment, *bombycinus* bears 5 "sensory" appendices, whereas *viduus* has 6. Whether this difference is constant and whether there are other reliable separating characters cannot be determined until more material of these species is available. Urogomphi as in figure 20, *d, f*.

Material used in study.—Only larval exuviae were available for examination. The specimen was reared from eggs secured from adults collected at Walla Walla, Wash., by H. P. Lanchester and identified by M. C. Lane. The parent adults were not retained. The exuviae are deposited in the U. S. National Museum.

LUDIUS MEDIANUS (Germar)

Diacanthus medianus GERMAR, Zeitschr. für die Ent., vol. 4, p. 71, 1843.

Corymbites rubidipennis LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 437, 1853.

Ludius medianus (Germar), BROWN, Canadian Ent., vol. 68, pp. 100-101, 1936.

This eastern species is recorded by Brown (1936b, p. 101) as occurring from central Manitoba to the Atlantic seaboard and as far south as Massachusetts. The only larvae known were collected from decomposing litter under spruce and were found to attack the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig).

The larva of *medianus* so strongly resembles that of the European *tessellatus* (Linnaeus) that separation is best made on the basis of distribution. In *medianus* the inner prongs of the urogomphi are only slightly longer than the outer prongs. This character suffices to distinguish the larva from its closest known American allies, *viduus* and *bombycinus*, in both of which the inner prongs are approximately twice as long as the outer prongs. The second segment of the antenna bears 5 "sensory" appendices and the legs carry as many spinelike setae as on the larvae of *viduus*.

Material used in study.—Two examples were examined, one being the last larval exuvium of a reared specimen. These were not collected at the same time or in the same location, but both were taken under spruce in New Brunswick.

1; South Branch, Kent County, New Brunswick; June 17, 1941; R. F. Morris; reared to adult. (C.N.C.)

LUDIUS PURPUREUS (Poda)

Elater purpureus Poda, Insecta Musei Gracensis, p. 41, 1761.

Ludius haematodes (Fabricius), ESCHSCHOLTZ, in Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.

Corymbites haematodes (Fabricius), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.

Corymbites purpureus (Poda), SEIDLITZ, Fauna Baltica, ed. 2, p. 173, 1888.

Corymbites (Anostirus) purpureus (Poda), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 366, 1927.

The larva of this central European species has been described by Nördlinger (1880, p. 8) and in greater detail by Beling (1883, pp. 262-265), who also refers to it in his later work (1884, p. 203). Henriksen's description (1911, pp. 264-265) appears to have been based upon the writings of Beling and not upon a personal study of specimens. Larvae of this species were not available for examination in the present study and the notes that follow were adapted from the literature referred to above. The inclusion of this species in the *fallax* group is made on the basis of apparent similarity of habitat of and structure in the larva of *purpureus* and those of *tessellatus* (Linnaeus) and *castaneus* (Linnaeus), as revealed in the writings of Beling and Henriksen.

According to Beling (1883, p. 265) the larvae live under the moss covering the forest floor and in meadows near forests. Pupation occurs in July or early August.

The larva strongly resembles *tessellatus* (Linnaeus), being distinguished by the following characters of the ninth abdominal segment: Near the middle of the dorsal plate, a transverse impression or groove unites 2 well-separated longitudinal impressions; caudal notch boot-jack-shaped, about as broad as long, only slightly narrowed posteriorly.

Length up to 19 mm., width up to 3.0 mm.; biconvex, but very flat, tape-shaped; noticeably well supplied with long setae; dorsum dirty yellow-brown shading to reddish brown, with a broad dark-brown transverse band across anterior part of each segment, giving larva a superficial banded appearance. Prothorax with fine sparse punctation; mediotergites of mesothorax and metathorax with somewhat stronger punctation, especially on anterior half; mediotergites of abdominal segments with relatively coarse, dense punctures.

* * *

LUDIUS AFFINIS (Paykull)

Elater affinis PAYKULL, Fauna Svecica, vol. 3, p. 12, 1800.

Ludius affinis (Paykull), ESCHSCHOLTZ, in Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.

Corymbites affinis (Paykull), GERMAR, Zeitschr. für die Ent., vol. 4, p. 63, 1843.

Corymbites (Haplotarsus) affinis (Paykull), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 381, 1927.

The larva of this European species is described by Beling (1883, pp. 276-278; 1884, p. 204). It is a woodland species, living chiefly in the litter and soil of drier parts of forests and to a lesser degree in decaying stumps. Pupation occurs in the last half of July and in early August. No reference to this species was found in the economic literature.

Beling's description is inadequate, both for the accurate identification of the larva and for determining its relationships. Specimens were not available for use in the present study.

The most important characters given by Beling may be summarized as follows: Up to 20 mm. in length and 2.5 mm. in breadth. Much flattened, moderately covered with hairs, and finely punctulate. Dorsum brown or yellowish brown. One "sensory" appendix on second segment of antenna. Mandible with relatively small retinaculum. Ninth abdominal segment flattened, with 3 well-rounded teeth on each lateral margin of dorsum. Urogomphi short and thick, bifid; outer prongs slightly larger than inner prongs and projecting obliquely upward. Caudal notch large, bootjack-shaped, wider than long, slightly narrowed posteriorly.

* * *

THE LUDIUS ROTUNDICOLLIS GROUP

FIGURES 14, *h, j*; 21; 22, *a, b, c, e*

KEY TO SPECIES

1. From North America; dorsum not distinctly patterned..... 2
 From Europe; dorsum with distinct pattern of bright brown spots on pale yellow background (fig. 22, *a*); urogomphal prongs subequal (fig. 22, *c, e*).....*cinctus* (Paykull) (p. 104)
2. Without definite impressions on mediotergites of mesothorax and metathorax; with conspicuous seta near center of each abdominal mediotergite (fig. 21, *e*); inner prongs of urogomphi small (*ipr*, fig. 21, *g*) 3
 Small, but definite impressions on mediotergites of mesothorax and metathorax; without conspicuous seta near center of each abdominal mediotergite; inner prongs of urogomphi moderately developed (*ipr*, fig. 21, *c, d*); eastern United States.....
 *sulcicollis* (Say) (p. 102)

3. Eastern United States; the most posterior of the blunt "teeth" (*to*, fig. 21, *f*) on lateral margins of dorsal plate of ninth abdominal segment more than one-half as long as broad.....
*rotundicollis* (Say) ("eastern species") (p. 96)
- Western United States; the most posterior of blunt "teeth" (*to*, fig. 21, *h*) on lateral margins of dorsal plate only one-half (or less) as long as broad.....*rotundicollis* (Say) ("western species") (p. 97)

On the basis of larval characters, three species have been included in this group, namely, *rotundicollis* (Say), *sulcicollis* (Say), and the European *cinctus* (Paykull). The larvae (figs. 21, *b*; 22, *a*) of these species are noticeably well supplied with setae and differ from all other *Ludius* larvae examined in having the proxistipes and dististipes clearly separated (fig. 22, *b*). All are wood inhabiting and appear to be chiefly predaceous; they are commonly found just under the bark of decaying stumps and logs or of living trees, frequently in the galleries of wood-boring beetles.

The species are quite distinct and easily recognized and it might be that two, or even three, closely related groups are represented by the species that have been brought together here. However, it is believed preferable to retain them in one group until larval material of other related species is available for study. On the basis of adult characters, Van Dyke (1932, p. 428) groups the following North American species: *rotundicollis* (Say), *sulcicollis* (Say), *rupestris* (Germar), and *nunenmacheri* Van Dyke. Larvae of the last two species were not available for examination.

The larva of the European *Ludius bipustulatus* (Linnaeus) resembles the *rotundicollis* group in color, general setal characters, nasale, and in several other respects; but it differs in urogomphal prongs, sculpture of abdominal segments, type of sternum in abdominal segments, pleurite of ninth abdominal segment, mandibles, and maxillary stipites.

Larvae of the *rotundicollis* group vary in color from bright brown to very dark brown, sometimes with the dorsum distinctly patterned (fig. 22, *a*), venter always pale. Caudal notch large, U-shaped. Urogomphi bifid; prongs subequal or outer prongs larger than inner prongs; tip of inner prong sharp, upturned; tip of outer prong bluntly rounded. Ninth abdominal segment (figs. 21, *g*; 22 *c*) with moderately large pits on dorsum; usually without setae (rarely with 2 small setae) on central dorsal area; 2 to 4 blunt "teeth" on lateral margins of dorsum; distance from pleural area to caudal notch approximates one-tenth to one-eighth total length of segment; and with large pleurite (*pl*, fig. 21, *h*) anteriorly on each side. Nasale uni-

dentate. Frontoclypeal area bluntly rounded posteriorly. Second joint of antenna bearing 1 "sensory" appendix. Without setae on basal joint of labial palpus. Eyes present. Gula elongate and narrow. Mandible with relatively small retinaculum set in slight depression. Presternum of prothorax divided into 3 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired (sometimes 2 most medial setae in semipaired arrangement), and transverse branches of impressions rarely exceeding one-half the distance from the longitudinal branches to the middorsal suture. On first to seventh abdominal segments sternum usually divided by lateral sutures into 3 pieces, pieces usually not completely separated. Anal aperture somewhat T-shaped.

LUDIUS ROTUNDICOLLIS (Say)

FIGURES 14, *j*; 21, *a, b, e-h*

Elater rotundicollis SAY, Ann. Lyceum Nat. Hist. New York, p. 259, 1825.

Corymbites rotundicollis (Say), LECONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 440, 1853.

Ludius rotundicollis (Say), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 427, 1932.

According to Van Dyke (1932, pp. 404, 427-428) this species occurs in both the "Atlantic States and Pacific States," the more typical *rotundicollis* being in the East and the subspecies *nigricans* (Fall) and *diversicolor* (Eschscholtz) in the West. In the present study, larvae identified as *rotundicollis* (Say) have been obtained from the extreme eastern and the extreme western parts of the United States. The specimens from the two regions are very similar, but sufficiently different in structure to suggest specific distinction.

"*Eastern species.*"—Larvae have been examined from Pennsylvania, Maryland, and New York State. The collectors' notes reveal that some specimens were taken from under bark on the trunk of an elm tree and others were observed attacking spiders in silken cocoons. Knull (1932, p. 43) reports the larvae as predaceous upon the larvae of cerambycids inhabiting the outer bark of numerous living deciduous trees. There are no records on the time of pupation, but Blatchley (1910, p. 768) observed the adults to hibernate beneath logs on sandy hillsides.

The larva of the "eastern species" may be distinguished from that of the "western species" by the following characters: Slightly paler in color, fewer setae, somewhat weaker punctation, a much more prominent posterior "tooth" (*to*, fig. 21, *f*) on the lateral margins

of the dorsal plate of the ninth abdominal segment, and without punctures in the region between the caudal notch and the pleural area of the ninth abdominal segment.

The largest larva examined was 14 mm. long and 2.5 mm. broad, but undoubtedly it was immature. Dorsum dark brown, eighth abdominal segment not darker than preceding segments. Each mediotergite on second to eighth abdominal segments with a posterior transverse row of 5 to 7 setae (8 to 15 setae in similar location in "western species").

Urogomphi (fig. 21, *f*) resemble those of "western species," but inner prongs relatively larger; outer prongs usually narrower at tips; and somewhat greater angle between prongs of each urogomphus.

"*Western species.*"—Van Dyke (1932, p. 428) states that the subspecies *nigricans* (Fall) ranges throughout western Washington and Oregon and south along the high Sierra Nevada whereas the other western subspecies, *diversicolor* (Eschscholtz), is a lowland form that breeds in the rotting parts of old living oaks. Larvae used in the present study were taken from bull pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga mucronata*) in Oregon and California.

This larva (fig. 21, *b*) is readily identified by its very dark brown color, great abundance of setae, and the characteristic urogomphi (*ur*, fig. 21, *g, h*).

Description of "mature" larva of "western species."—Length 22 mm.; greatest breadth 3.5 mm. on fourth abdominal segment. A fully distended larva measured 24 mm. Body robust; convex dorsally, flatter ventrally; abundantly provided with setae; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum dark brown, sometimes approaching black brown; head, prothorax, and eighth and ninth abdominal segments usually very dark; on abdominal segments pigmentation is stronger posterior to imaginary line joining transverse branches of impressions on mediotergites; venter pale yellow to creamy white, darker on ventral surface of head and terminal part of ninth abdominal segment. Dorsum slightly rugose, moderately to densely punctate, punctures small except on ninth abdominal segment.

Head (fig. 21, *a*) subquadrangular with slightly arcuate sides; not as thick at base as long; flattened above and below.

Frontoclypeal region extending backward to or almost to foramen magnum, bluntly rounded posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting of transverse

ridge; serrate when uneroded, with at least 5 or 6 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates punctulate. Dorsal sulci (*ds*) shallow and inconspicuous; each bearing 5 setae, subequally spaced, the most anterior hair being very long, the next seta small and the 3 most posterior setae very small. Usually 1 to 3 prominent setae anterad to dorsal sulci. Ventral sulci bearing row of 7 to 9 setae, usually about 6 or 7 conspicuous. Two pairs of long lateroepicranial setae (*led*, *lev*, fig. 21, *a*); also 1 seta farther dorsad and 1 or 2 unpaired setae farther anterad or anterodorsad (in region between paired setae and setae surrounding eye spot); sometimes additional minute setae scattered over surface. Eye spot (*e*) black, well defined, ovate or circular; surrounded by 5 or 6 unpaired setae. Postgenal areas slightly expanded mesad; glabrous.

Gula elongate, narrow; glabrous.

Antenna with first segment clavate, about two-thirds as wide as long; without setae; 3 to 5 small pores. Second segment subcylindrical, two-thirds as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third segment. Terminal segment small, three-fifths as long as second segment and one-third as wide; a few setae on apex, 1 usually larger than others.

Mandible of moderate length, robust; about two-thirds as wide at base as long; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with moderately deep dorsal groove; inner face slightly excavate with longitudinal carina; ventral margin of inner face sharp and slightly convex ventrally, extending backward past retinaculum to near mesal aspect of base of mandible; dorsal margin of inner face sharp and strongly convex dorsally, extending backward to posterior limit of retinaculum. Retinaculum small for size of mandible, base somewhat recessed between elongate margins of inner face of anterior part of mandible.

Ventral mouthparts only two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, wider anteriorly, inner margin straight, outer margin slightly convex; proxistipes and dististipes distinct (as in *cinctus*, fig. 22, *b*); usually 4 to 6 prominent setae on antero-lateroventral aspect, with 1 or 2 small setae farther caudad. Galea with basal joint subcylindrical, shorter than terminal joint, without setae or pores; terminal segment narrower than basal segment, outer margin longer than inner

margin, with 4 or 5 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; 5 or 6 small pores and 2 setae on ventral surface. Second segment as long as wide; as long as first segment and almost as wide; without setae; 2 or 3 pores. Third segment wider than long; about one-half length of second segment; 4 or 5 pores ventrally; distally with 1 or 2 small setae on mesoventral aspect and 1 seta on lateral aspect. Fourth segment longer than wide; longer than third segment; 1 small seta proximally on dorsal aspect; without pores. Postmentum elongate, almost twice as wide anteriorly as posteriorly; 1 long seta at each posterior corner, 2 long setae near each anterior corner; 1 or more setae along each side; few minute pores. First prementum with 2 (sometimes more) prominent setae just caudad to base of each palpus, forming transverse row of at least 4 setae. Labial palpi with basal joint cylindrical or slightly clavate, more than one-half length of prementum, longer than wide, without setae, 2 to 4 pores; terminal segment more than one-half length and about one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; with from 30 to 45 setae (on each side of median dorsal suture) arranged as follows: anteriorly with 15 to 20 setae in a confused transverse row (most abundant laterally), posteriorly with 6 to 10 setae in an irregular transverse row, and 10 to 15 setae scattered between these rows mostly near the lateral margin. Episternum with 3 large setae. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: a small posterior median sclerite, anteriorly attenuate, with 2 small setae anteriorly; 2 large, subtriangular lateral sclerites (sometimes joined anteriorly), striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 4 or 5 minute setae on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites rugulose; punctulate; transverse branch of impression indefinite, consisting of a few disconnected punctures; longitudinal branch wanting. Each mediotergite bearing about 20 setae, usually arranged as follows: posterior transverse row of 6 to 10 setae, 8 to 10 setae along lateral margin, 2 or 3 slightly farther mesad and 1 long seta near center of sclerite. Posterior laterotergite large, subovate or subtriangular, bearing 1 large seta near dorsal margin. Anterior

laterotergite subtriangular or subovate, at least one-half as large as posterior laterotergite. Mesothoracic spiracle set in strongly margined circular orifice; much larger than abdominal spiracles. Episternum bearing 4 or 5 fine setae, but without spinelike setae. Eusterium with 6 fine setae (only 2 conspicuous) in transverse row.

Legs subequal in length. Coxae of prothoracic legs with up to 8 spinelike setae and several fine setae on anterior aspect, on mesothoracic and metathoracic legs with up to 14 spinelike setae and 5 to 8 fine setae, spinelike setae mostly in 1 row; a few fine setae scattered on posterior surface. Trochanter with 5 or 6 spinelike setae on medioanterior surface; 1 to 4 such setae and 2 or 3 fine setae scattered on posterior surface; 2 well-developed setae on medial aspect. Femur slightly longer and about as wide as trochanter; usually with 7 to 10 spinelike setae on medioanterior surface; 3 or 4 spinelike setae and 1 or 2 slender setae on posterior surface; 1 long seta on medial aspect; a few fine setae on lateral surface. Tibiotarsus with 4 fine setae around distal margin; 3 or 4 spinelike setae and 1 slender seta on medioanterior surface; 1 to 3 spinelike setae on posterior surface. Ungula, when uneroded, about two-thirds as long as tibiotarsus; base well expanded mesally with relatively long medial sclerite bearing 2 fine setae.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 21, *e*) with scattered small punctures, sometimes more abundant anteriorly; transverse branch of impression (*trim*) dark, slightly sinuate, with 6 to 9 minute punctures subequally spaced, on second to eighth segments reaching from one-third to one-half distance from longitudinal branch to middorsal suture, shorter on first segment and slightly longer on seventh and eighth segments; longitudinal branch of impression (*loim*) extending less than one-half distance from transverse branch to posterior transverse row of setae. Each mediotergite bears from 15 to 25 setae, usually arranged as follows: posterior transverse row of 8 to 15 unpaired setae, lateral group of 6 to 10 setae, and 1 seta toward center of sclerite; a few exceedingly minute setae sometimes observable on anterior part of sclerite. Laterotergite I extending almost whole length of segment; with 6 to 12 setae, mostly on dorsal and posterior aspects. Pleurite large, subovate, pale, usually with 6 to 12 long setae; size of sclerite and number of setae decrease from first to eighth segment. Sternum divided into 3 parts on first to seventh segments, inclusive, forming 2 laterosternites and 1 larger mediosternite; laterosternites each with from 4 to 6 setae,

mostly along lateral margin; mediosternite bearing from 4 to 8 setae and 2 very faint impressions meeting medially; sternum undivided on eighth segment.

Ninth abdominal segment (fig. 21, *g, h*), exclusive of urogomphi, about as long as eighth abdominal segment and at least three-fourths as wide; five-sixths to seven-eighths as long as wide; widest anteriorly; width at anterior margin of caudal notch about three-fourths to five-sixths greatest width of segment. Dorsum convex, sloping downward from front to back. Dorsal plate (*dpla*) irregularly wrinkled; densely punctate, punctures moderately large and deep; a pair of paramedian impressions (*pim*) converge posteriorly but do not meet; lateral impressions usually obliterated by submarginal depression; usually without setae (rarely with 2 small setae anteriorly) except at lateral margins, which are strongly raised and carinate, bearing 2 or 3 blunt "teeth" (*to*), only the most posterior being prominent; transverse impression (*trim*) dark and strong, continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; densely punctured throughout with a few larger pits anteriorly on lateral aspects; usually with from 15 to 25 setae on each side, sometimes more. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-eighth of total length of segment (exclusive of urogomphi). Pleural area (*pl*) large, consisting of transversely striated membrane except at each anterior end, where there is a large pleurite which is posteriorly attenuate and bears 1 to 3 setae. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite with about 10 setae, mostly in irregular row around tenth abdominal segment.

Urogomphi (*ur*, fig. 21, *g, h*) large, separate, bifid near tip, punctulate; prongs short, outer prong larger. Inner prong (*ipr*) small, fleshy with horny tip; arising from medial or medioventral margin of distal one-third of urogomphus; projecting caudad with upturned tip (sometimes eroded); without setae or tubercles. Outer prong (*opr*) short, robust, three times as wide as inner prong and longer; projecting dorsocaudad, terminating in blunt round tip (sometimes very broad at tip); without setae or tubercles. Undivided part of urogomphus usually with linear depression on ventral aspect at point of separation of prongs; 1 large seta on lateral aspect arising from deep cup with raised anterior margin; 4 to 6 setae ventrally, usually arranged as follows: 1 or 2 setae in depression between bases of prongs, 1 or 2 setae mesad to this depression and anterad to base

of inner prong, 2 or 3 setae laterad to depression and anterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped; as long as wide or longer than wide; usually not narrowed posteriorly.

Tenth abdominal segment (*10*) with 20 or more setae in irregular whorl around distal end; anal aperture somewhat T-shaped with transverse portion to the rear.

Material used in study.—"Eastern species": Eight examples of this species were examined, including two larval exuviae that were believed to be associated with reared adults, but the adults were not available. These larval skins were from specimens collected at Mont Alto, Pa., January 25, 1931, J. N. Knull; apparently identified by Knull; (Pennsylvania Agricultural Experiment Station collection). The whole larvae examined were from Pennsylvania (4), New York (1), and Maryland (1) and are deposited in the U. S. National Museum.

"Western species": Seven examples, including one larval exuvium of a reared specimen, were studied. Unfortunately, the reared adult could not be found. This specimen was from Colony Mills, Sequoia Park, Calif., July 15, 1918; adult found in bottom of rearing cage September 29, 1919; F. C. C. (U.S.N.M. Hopk. U.S. 10652b). The whole larvae examined were from Oregon (3) and California (3) and are deposited in the U. S. National Museum.

LUDIUS SULCICOLLIS (Say)

FIGURE 21, *c, d*

Elater sulcicollis SAY, Trans. Amer. Philos. Soc., vol. 6, p. 168, 1836.

Corymbites sulcicollis (Say), LeCONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 441, 1853.

Ludius sulcicollis (Say), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 400, 1932.

Van Dyke (1932, p. 400) indicates that this species is distributed throughout the Atlantic States, and Leng (1920, p. 169) records it as far inland as Indiana.

The larvae are reported by Knull (1930, p. 83; 1932, p. 43) to inhabit decaying wood of sour gum (*Nyssa sylvatica*) and pitch pine (*Pinus rigida*) and hibernating adults have been taken by Blatchley (1910, p. 768) from under the loose bark of an ash snag. Knull (1932, p. 43) found an adult in its pupal cell on August 16, which suggests that the time and period of pupation are similar to those of most species of *Ludius*.

This larva is readily distinguishable from *rotundicollis* (Say) by its much paler color, relatively larger inner prongs on urogomphi (*ipr*, fig. 21, *c, d*), the presence of small but definite impressions on mediotergites of mesothorax and metathorax, and the absence of a seta near the center of each mediotergite of first to eighth abdominal segments. *Sulcicollis* resembles more closely the "eastern species" of *rotundicollis* than the "western species"; the similarity is most pronounced in the setation, the "western" *rotundicollis* bearing many more setae.

Length 15 mm.; greatest breadth 2.75 mm. A fully distended larva measured 21 mm. Dorsum chestnut brown, eighth and ninth abdominal segments darkest; on mediotergites of abdominal segments the pigmentation is slightly deeper in the regions lying within the angles of the impressions. Dorsum slightly rugose, moderately to densely punctate, punctures small, except on ninth abdominal segment.

Epicranial plates with 2 pairs of large lateroepicranial setae and 1 large seta farther dorsad, but without setae between the region of the paired hairs and the setae surrounding the eye; setae anterad to dorsal sulcal setae are either minute or wanting.

Tergites of prothorax each with from 18 to 30 setae; each mediotergite of mesothorax and metathorax bears 13 to 20 setae; and each mediotergite of abdominal segments carries 9 to 16 setae. Sternum of first to seventh abdominal segments divided as in *rotundicollis*, but bearing only about 7 to 10 setae.

Coxa of prothoracic legs with up to 12 spinelike setae on anterior surface, mesothoracic and metathoracic legs with up to 20 spinelike setae.

On ninth abdominal segment, region between pleurite and caudal notch without punctures and approximating one-tenth to one-eighth total length of segment, exclusive of urogomphi.

Urogomphi (fig. 21, *c, d*) large, separate, bifid, punctulate. Inner prong (*ipr*) small, about one-half size of outer prong, corniform, projecting mesocaudad with sharp, upturned tip; bearing 2 long setae, 1 ventrally at base of prong, the other at junction with outer prong. Outer prong (*opr*) large, fleshy, projecting dorsocaudad, sometimes slightly laterad, terminating bluntly rounded; with 1 large seta on anterolateral aspect near base of prong. Undivided part of urogomphus with 2 large setae ventrally just anterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped, usually broader than long; usually not narrowed posteriorly.

Material used in study.—Six specimens were examined, including one larval exuvium. Though reared adults were not available for confirmation of the identity of the material studied, it is believed to be reliably named. The larval skin examined is from the Pennsylvania Agricultural Experiment Station collection and is labeled "*Ludius sulcicollis* Say, Cold Springs, Pa., VIII-16, J. N. Knull." In his "Notes on Coleoptera—No. 3," Prof. Knull (1932, p. 43) states, "LUDIUS SULCICOLLIS Say. An adult was found in its pupal cell in a decayed pitch pine (*Pinus rigida* Miller) snag at Cold Springs, Adams County, August 16." It is very likely that the larval exuvium examined was taken with its adult from the pupal cell referred to in this statement. Three whole larvae in the U. S. National Museum labeled "*Ludius sulcicollis* (?) Say, Hummelstown, Pa., V-20-'29, J. N. Knull, *Nyssa sylvatica*" are thought to be associated with the material of this species that was reared by Prof. Knull and reported by him (1930, p. 83) as follows, "LUDIUS SULCICOLLIS Say. Adults were reared from dead sour gum (*Nyssa sylvatica*) wood infested with *Leptura emarginata* Fab. and *Charisalia americana* Hald. collected at Hummelstown, Pennsylvania." The other larvae examined were from Pennsylvania (1) and Illinois (1).

LUDIUS CINCTUS (Paykull)

FIGURES 14, *h*; 22, *a-c, e*

Elater cinctus PAYKULL, Fauna Svecica, vol. 3, p. 10, 1800.

Hypoganus cinctus (Paykull), KIESENWETTER, Naturgeschichte der Insecten Deutschlands Coleoptera, 1857-1863, vol. 4, p. 299, 1858.

Corymbites cinctus (Paykull), BOSE, Die Käfer Deutschlands von Valentin Gutfleisch, p. 363, 1859.

Hypoganus cinctus (Paykull), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 402, 1927.

The larva of this European species has been described by Schiodte (1870, p. 519), Rupertsberger (1870, pp. 835-836), and Henriksen (1911, pp. 263-264) and is referred to by Beling (1884, p. 204).

The larval habitat is in decaying stumps and logs, particularly of oak and beech. Specimens are commonly found just under the bark and have been taken from the galleries of *Anobium*. Henriksen (1911, p. 264) states that pupation occurs in August and the imago develops in September, spending the winter in its pupal chamber.

The larva of *cinctus* is readily identified by its prominent color pattern (fig. 22, *a*), subequal prongs of urogomphi (fig. 22, *c*), and large number of setae, especially on medial aspect of femur and trochanter. The color pattern and lavish supply of setae give super-

ficial resemblance to the larva of *bipustulatus* (Linnaeus), which is readily separated on the basis of group characters.

Length 13.6 mm.; greatest breadth 2.75 mm. Fully distended larvae measured up to 18.5 mm. Conspicuous color pattern on dorsum (fig. 22, *a*) consists mainly of bright-brown or reddish-brown patches on pale yellow background, giving superficial appearance of four longitudinal dark bands. The darkest and most conspicuous coloring is on the anterior four-fifths of head, anterior two-thirds of prothorax, dorsal plate of ninth abdominal segment, and within the angle of impressions on mediotergites of first to eighth abdominal segments. The paramedial patches on first to eighth abdominal segments are large, irregular, and lighter in color. Dorsum slightly rugose; densely punctate on ninth abdominal segment; a few smaller punctures on other abdominal segments; head and prothorax minutely punctulate.

Maxillary palpus with fourth segment at least twice as long as third segment.

Setae even more abundant than in *rotundicollis*, being most significant in the following regions: Epicranial plates each bear 8 or 9 large setae near center of lateral area, usually arranged as a group of 5 or 6 setae with 1 seta farther dorsad and 2 setae farther anterad; each tergite of prothorax carries 35 to 50 setae; each mediotergite of mesothorax and metathorax bears 20 to 30 setae; medial aspect of femur with up to 8 slender setae; medial aspect of trochanter with 4 to 8 slender setae; each mediotergite of abdominal segments bears 15 to 25 setae; sternum of first to eighth abdominal segments bears up to 20 setae.

Sternum of first to eighth abdominal segments subquadrate, with a deep impression on each side which almost or entirely separates off laterosternites.

On ninth abdominal segment (fig. 22, *c*), lateral margins of dorsum bear 3 or 4 blunt "teeth"; area between pleurite and caudal notch is without punctures and approximates one-tenth (or less) of total length of segment, exclusive of urogomphi.

Urogomphi (*ur*, fig. 22, *c*; fig. 22, *e*) separate, bifid; prongs subequal and very finely punctulate. Inner prong (*ipr*) large, smooth, somewhat corniform; projecting backward, slightly inward and upward, with short, sharp tip turning abruptly upward; usually with 3 setae at base on ventrolateral aspect, at least 1 being near junction with outer prong. Outer prong (*opr*) large, smooth, subcylindrical, projecting caudodorsad, terminating bluntly rounded; 1 very minute seta on inner aspect about halfway along prong, 1 large seta on

anterolateral aspect of base and 1 large seta on lateral aspect of base or farther forward on undivided portion of urogomphus.

Caudal notch (*cn*) large, U-shaped, wider than long; anterior margin almost straight; wide posteriorly, but somewhat narrowed by tips of inner prongs.

Tenth abdominal segment with approximately 25 fine setae in irregular whorl; anal aperture T-shaped, with transverse portion to the rear.

Material used in study.—Examination was made of 15 specimens, all from Denmark. Some of the material had been used by K. L. Henriksen in his description of the species. Specimens examined are deposited in the U. S. National Museum and the Canadian national collection. Notes are given below concerning 2 reared specimens for which the larval exuviae and associated adults were available.

1; Dyrehaven, Denmark; Sept. 8, 1895; under bark of oak in pupal cell; E. Rosenberg. (U.S.N.M.)

1; Denmark; August 1915; in oak; J. P. Kryger. (U.S.N.M.)

* * *

LUDIUS BIPUSTULATUS (Linnaeus)

FIGURES 14, *c*; 22, *d, f*

Elater bipustulatus LINNAEUS, *Systema naturae*, ed. 12, vol. 1, p. 652, 1767.

Corymbites bipustulatus (Linnaeus), BOSE, *Die Käfer Deutschlands von Valentin Gutfleisch*, p. 363, 1859.

Selatossomus bipustulatus (Linnaeus), SEIDLITZ, *Fauna Baltica*, ed. 2, p. 171, 1888.

Corymbites (Calambus) bipustulatus (Linnaeus), SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 385, 1927.

The only larva of this European species that was available for examination was collected under apple bark at Drochtersen, Germany. DuBuysson (1888, p. 15) refers to the larva as being exclusively carnivorous. Superficially it resembles larvae of the *Ludius rotundicollis* group.

The principal diagnostic characters of this species follow: Dorsum distinctly patterned (fig. 22, *f*) with dark brown patches over a pale yellow background; caudal notch large, U-shaped; urogomphi (*ur*, fig. 22, *d*) bifid, inner prongs much larger than outer prongs; tips of prongs bluntly rounded; nasale unidentate; proxistipes and dististipes not distinct; presternum of prothorax divided into 3 pieces; without spinelike setae on episterna of mesothorax and metathorax; mediotergites of abdominal segments with prominent setae unpaired

and transverse branches of impressions (*trim*, fig. 22, *f*) reaching to middorsal suture in second to eighth segments; sternum undivided in first 8 abdominal segments; and anal aperture linear and median.

Description of larva.—Length 9 mm.; greatest breadth 1.75 mm. on third to fifth abdominal segments. Only one larva was available for examination and its relative maturity is unknown. Body robust; convex dorsally, flatter ventrally; depressed dorsoventrally; with large membranes on lateral aspects; all segments broader than long; head and ninth abdominal segment about three-fifths greatest body width. Dorsum with conspicuous color pattern (fig. 22, *f*), consisting mainly of dark brown patches on pale yellow background, giving superficial appearance of 4 dark longitudinal bands. On first 8 abdominal segments the dark color all lies posterad to transverse branches of impressions and mediad to longitudinal branches; on each segment there are 2 subrectangular, paramedian patches connected anteriorly with lateral areas of similar pigmentation; remaining portions are pale yellow, except for brown, striate posterior margin of mediotergites and light brown area anterad to impressions. On ninth abdominal segment the dorsal plate and urogomphi are dark brown, dorsal plate somewhat paler laterally. On mesothorax and metathorax the dark coloring is less intense than on abdomen, but pattern is similar except laterally where there are 2 or 3 dark spots instead of 1 large patch. On prothorax the dorsal surface is light brown with somewhat suffused irregular dark brown areas, except for yellow-brown posterolateral patches and narrow medial area. Anterior two-thirds of head dark brown and frons dark throughout. Venter pale, unicolorous, except for dark urogomphi, ventral margin of caudal notch, and ventral mouthparts. Dorsum slightly rugose; sparsely punctulate, punctures most conspicuous on epicranial plates, prothorax, and ninth abdominal segment.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region extending backward to near foramen magnum, bluntly rounded posteriorly. Nasale unidentate. Subnasale with transverse ridge, ventrally convex, serrate when uneroded, bearing 5 subequal, short, sharp, forward-projecting denticles.

Epicranial plates punctulate. Dorsal sulci each bearing 5 setae, subequally spaced, the most anterior seta long, others small. Two pairs of lateroepicranial setae; also 1 seta farther dorsad and 1 small seta farther anterodorsad. Eye spot black, well defined, ovate or circular, surrounded by 4 or 5 setae, 4 conspicuous.

Gula elongate, narrowed in middle; glabrous.

Antenna with first segment clavate, three-fourths as wide as long. Second joint subcylindrical, almost as wide as long; one-half length of basal joint; on specimen at hand, right antenna with 1 large, conical "sensory" appendix, left antenna with 2 such appendices. Terminal segment as long as second joint and one-third as wide.

Mandibles about two-thirds as wide at base (ventral aspect) as long; retinaculum of moderate length. Distal half inward bending; pointed; outer surface convex with moderately deep dorsal groove; inner face slightly excavate with small median carina; ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, wider anteriorly; proxistipes and dististipes not distinct; 4 setae on antero-lateroventral aspect. Galea with basal joint ring-shaped; half as long as terminal joint; terminal segment narrower than basal joint. Maxillary palpus with first segment ring-shaped; much wider than long. Second joint subcylindrical; as long as wide; longer than first joint and three-fourths as wide. Third segment ring-shaped; much wider than long; about one-half length of second joint. Fourth joint longer than wide; longer than third joint. Postmentum subrectangular with 1 long seta near each corner. First prementum with 2 or 3 setae just caudad to base of each palpus, making transverse row of 4 to 6 setae. Labial palpus with basal joint cylindrical, longer than wide, without setae; terminal joint small, more than one-half length and about one-half width of basal segment.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; one-third wider than long. Tergites minutely punctulate; with about 23 setae on each side of median dorsal suture arranged as follows: anteriorly with 10 to 12 setae in an irregular transverse row; posteriorly with 9 unpaired setae in transverse row, some minute, but mostly long; 3 setae along lateral part of tergite, the middle seta of the 3 being farthest mesad. Presternal area consisting of 3 sclerites as follows: 1 small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 4 minute setae on anteromedial aspect.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites slightly rugose, punctures minute and sparse; transverse branches of impressions reaching about one-third distance from

longitudinal impressions to middorsal suture; longitudinal branches short, with 1 large seta (sometimes also 1 small seta) at posterior ends. Posterior part of each mediotergite with transverse row of 7 or 8 conspicuous unpaired setae. Lateral part of each mediotergite with 3 or 4 large setae. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Mesothoracic spiracles small, but slightly larger than spiracles in abdomen. Episternum without spinelike setae.

Legs subequal in length. Coxae of prothoracic legs with about 12 spinelike setae on each anterior surface, up to 17 such setae on coxae of mesothoracic and metathoracic legs; sometimes 1 stout seta and a few fine setae on posterior surface. Trochanter with 4 to 6 spinelike setae on medioanterior surface; 2 or 3 such setae and 1 fine seta on posterior surface; 2 long setae on medial aspect. Femur longer than trochanter and as wide; with 6 to 8 spinelike setae on medioanterior surface; 1 to 3 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; distally with 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 2 or 3 spinelike setae and 1 slender seta on medioanterior surface; 1 or 2 spinelike setae and 1 slender seta on posterior surface. Ungula, when uneroded, about three-fourths as long as tibiotarsus; base well expanded mesally, with 2 fine setae arising mesally from small proximal sclerite.

First to eighth abdominal segments subequal; first segment practically as long as others; all segments about twice as wide as long; third to fifth segments widest. Mediotergites (*mtg*, fig. 22, *f*) with scattered minute punctures; transverse branches of impressions (*trim*) reaching to middorsal suture on second to eighth segments, only about half as long on first segment; longitudinal branches of impressions (*loim*) extending almost to posterior transverse row of setae. Each mediotergite with about 15 to 18 unpaired setae, arranged as posterior transverse row of about 12 setae (6 or 7 conspicuous), with 3 to 6 setae along lateral margin of sclerite. Laterotergite I bearing 3 to 5 setae. Spiracles small, subequal; spiracular sclerite small, ovate, usually just anterad to middle of segment. Pleurite well developed, subovate, slightly diminishing in size from first to eighth segments; posteriorly with 2 or 3 setae in transverse row. Sternum of 1 piece; subquadrate, narrower posteriorly; bearing about 8 setae.

Ninth abdominal segment (fig. 22, *d*), exclusive of urogomphi, slightly longer than eighth abdominal segment and three-fourths as wide; three-fourths as long as wide; widest anteriorly; width at an-

terior margin of caudal notch about three-fourths greatest width of segment. Dorsum convex, sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sparsely punctulate; impressions indefinite, usual lateral pair practically obliterated by submarginal depressions; 2 faint paramedian impressions (*pim*) converge posteriorly, almost meeting; without setae except at lateral margins, which are raised and carinate, bearing 2 prominent blunt setiferous teeth (*to*) and 1 or 2 smaller teeth farther anterad and slightly more ventrad; transverse impression (*trim*) continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; with from 15 to 18 setae on each side, some issuing from small sclerotized tubercles; distance between anterior margin of caudal notch and posterior margin of pleural area approximates one-fifth of total length of segment (exclusive of urogomphi). Pleural area transversely striate. Sternum of 2 sclerites, each with 5 setae.

Urogomphi (*ur*, fig. 22, *d*) large, separate, bifid, finely punctulate dorsally; projecting caudad; prongs unequal. Inner prong (*ipr*) large, projecting backward and slightly upward, terminating bluntly rounded; 1 prominent seta on ventrolateral aspect halfway along prong, issuing from a deep socket with raised anterior margin; 2 setae ventrally. Outer prong (*opr*) just a small round knob much like the blunt "teeth" on sides of dorsal plate; projecting dorsocaudad; 1 long seta issuing from apex and 1 short, fine seta from mesal aspect of base. Undivided part of urogomphus with 2 long setae, 1 ventrally and 1 just laterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped, longer than wide.

Tenth abdominal segment with whorl of 10 fine setae and a few shorter hairs scattered over surface; anal aperture linear and median.

Material used in study.—The only larva available to the writer was received through the courtesy of Dr. Fritz van Emden, of the British Museum, London, in whose private collection it is stored. This larva was labeled "*Hypnoidus pulchellus* L. or *Selatosomus bipustulatus* L.?" However, Dr. van Emden kindly compared the illustrations prepared from this specimen with a larva and a larval skin (associated with an adult of *Corymbites bipustulatus* reared by C. O. Waterhouse) that he later found in the Museum collection. He states, "There can be no doubt whatever that this larval skin is conspecific with my larva, which you have figured."

THE LUDIUS NITIDULUS GROUP

FIGURES 13, *a*; 14, *i*; 23

KEY TO SPECIES

1. From North America; outer prongs of urogomphi about twice as large as inner prongs (fig. 23, *e, g*)..... 2
 From Europe; outer prongs of urogomphi not larger than inner prongs or only slightly larger (fig. 23, *f*)...*nigricornis* (Panzer) (?) (p. 118)
2. Nasale and adjoining area of frons deeply sunken; nasale (fig. 23, *c*) narrow, tip divided into 3 narrow, forward-projecting denticles....
*rufopleuralis* Fall (?) (p. 117)
 Nasale and adjoining area of frons only slightly depressed; nasale (*n*, fig. 23, *a*) broad, tip tridentate, median denticle largest, lateral denticles projecting anterolaterad.....*nitidulus* (LeConte) (p. 112)

Knowledge of this group is based upon larvae of *nitidulus* (LeConte) and upon larvae that are believed to be *rufopleuralis* Fall or *aratus* (LeConte) and other unidentified larvae that are regarded as the European *nigricornis* (Panzer) or a closely related species.

From the fragmentary data that are available, the principal larval habitat appears to be the litter of the forest floor. The larvae are believed to be chiefly predaceous.

These larvae differ from other known *Ludius* larvae in possessing 2 conspicuous dorsal posteroepicranial setae (*ped*, fig. 23, *a*) on each side of the frontal sutures near the posterior limit of frons. In this they resemble the larvae of *Cryptohypnus*, *Melanactes*, and the Australian genus *Crepidomenus*. However, the *nitidulus* group is readily distinguished from these genera by the following combination of characters: Eyes present; outer urogomphal prongs (*opr*, fig. 23, *e*) curving forward; blunt "teeth" on the lateral margins of the dorsal plate of the ninth abdominal segment (*to*, fig. 23, *g*); abdominal mediotergites (fig. 23, *b*) without conspicuous transverse rugae and with impressions reaching to or almost to the middorsal suture on second to eighth segments; and setal pattern on abdominal mediotergites as figured.

The larvae are yellowish brown. Moderately large caudal notch, U-shaped. Urogomphi bifid; prongs subequal or outer prongs larger than inner prongs; tips of prongs sharp, tips of outer prongs inclined forward. Ninth abdominal segment (fig. 23, *g*) with 3 prominent blunt "teeth" on lateral margins of dorsum and typically with 4 setae on the central dorsal area. Nasale (*n*, fig. 23, *a*; fig. 23, *c, d*) with tip tridentate, denticles of varying character. Frontoclypeal area (fig. 23, *a*) broadly rounded posteriorly. Second joint of antenna bearing 1 sensory process. Gula of moderate width and length. Mandi-

bles much as in *aeripennis*, but in distal half the ventral margin of inner face is straight rather than slightly convex. Basal segment of each labial palpus with 1 to 3 setae. Eyes present. Presternum of prothorax divided into 2 pieces (fig. 13, *a*). Episterna of mesothorax and metathorax without spinelike setae. One seta (*atm*, fig. 23, *b*) on each side of middorsal suture (close to suture) in anterior half of each thoracic segment and in the first 8 abdominal segments. Mediotergites of abdominal segments 1 to 8 with prominent setae unpaired.

LUDIUS NITIDULUS (LeConte)

FIGURES 13, *a*; 14, *i*; 23, *a, b, e, g*

Corymbites nitidulus LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 439, 1853.
Ludius nitidulus (LeConte), BROWN, Canadian Ent., vol. 68, p. 18, 1936.

According to Brown (1936a, p. 19) this northern species is known from the Atlantic coast as far west as Edmonton, Alberta.

The larvae have been collected in New Brunswick from the litter under spruce, in northern Saskatchewan from leafy debris in well-established groves of aspen poplar (*Populus tremuloides*) and from the deep, damp litter under mixed stands of poplar, spruce, and paper birch. On August 10 an adult with its larval and pupal exuviae was found in its pupal chamber by the side of a poplar root about 1 to 1½ inches below the surface of the leaf litter.

The larva is readily distinguished from its nearest relatives as follows: Nasale and adjacent part of frons only slightly sunken; nasale (*n*, fig. 23, *a*) broad, lateral denticles short and projecting anterolaterad; and outer prongs of urogomphi (fig. 23, *e*) twice as large as inner prongs.

Description of larva.—Length 14.5 mm.; greatest breadth 2.5 mm., on fourth abdominal segment. The largest specimen examined measured 17.5 mm. but even this larva may not have been full grown. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown ("buckthorn brown," Ridgway, 1912); darker on mandibles, nasale, talus, and tips of prongs or urogomphi; venter slightly paler. Dorsum slightly rugose; sparse shallow pits; short, inconspicuous transverse rugae (or pits) just anterad to transverse branches of impressions on abdominal segments.

Head subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region (fig. 23, *a*) with posterior part extending backward to or almost to foramen magnum (*for*); broadly rounded (almost truncate) posteriorly. Nasale and adjoining parts of frons only slightly sunken. Nasale (*n*) well developed; tridentate at tip; median denticle largest; lateral denticles appear as lateral expansions of median tooth; 1 robust seta arising from dorsal aspect of base of each lateral denticle. Subnasale with sclerotized transverse ridge, possibly serrate when uneroded, but no serration in material at hand, all of which has been badly eroded. Paranasal lobes produced beyond nasale.

Epicranial plates bearing small shallow pits. Two conspicuous dorsal posteroepicranial setae (*ped*, fig. 23, *a*), one on each side of frontal sutures near posterior limit of frons. Dorsal sulci with 5 setae subequally spaced, the most anterior seta very long, the next of moderate length and farthest laterad, others very small. Ventral sulci bearing row of 7 to 9 setae, usually 4 or 5 conspicuous. Two pairs lateroepicranial setae with 1 small or minute seta caudad to more ventral pair and sometimes a few minute setae scattered over lateral aspect of genae. Eye spot black; well defined, ovate or circular; surrounded by 4 or 5 setae; usually 1 additional seta short distance caudad to most dorsal of setae surrounding eye. Postgenal areas expanded mesally, sometimes almost meeting; 1 minute seta in area near ventral head ridge.

Gula of moderate length and width; glabrous.

Antenna with first joint clavate, two-thirds to three-fourths as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few minute setae borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third segment. Terminal joint small, at least one-half length of second joint and about one-third as wide; 4 setae on apex.

Mandible of moderate length, robust, about two-thirds as wide at base as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina; ventral margin of inner face sharp, straight or very slightly convex ventrally; dorsal margin of inner face sharp, strongly convex dorsally.

Ventral mouthparts three-fourths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 5

or 6 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, slightly shorter than terminal joint; terminal segment narrower than basal joint, a few pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment about as wide as long. Second segment as long as wide; slightly narrower than first joint; without setae; a few pores. Third joint wider than long; about one-half length of second segment; 3 or 4 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 on lateral aspect. Fourth segment slightly longer than wide; fully as long as third joint; without setae or pores. Postmentum slightly wider anteriorly; 1 or 2 setae near each corner; 1 or more minute setae along each lateral margin. First prementum with 2 setae just caudad to base of each palpus, making transverse row of 4 setae. Labial palpus with basal joint subcylindrical, at least one-half length of first prementum, slightly longer than wide, 1 or 2 prominent setae distally on medioventral aspect, few pores; terminal segment about one-half length and one-half width of basal segment; without setae; usually with 1 pore.

Prothorax almost as long as combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites punctulate; anterior part of each tergite with 8 to 14 unpaired setae in irregular transverse row, 1 seta on each tergite being close to mid-dorsal suture; posterior part of each tergite with 5 to 7 setae in irregular transverse row, 2 most medial setae usually paired or semi-paired; 1 or 2 unpaired setae laterad to central areas of sclerite. Episternum with 3 large and a few small setae; 2 minute setae between episterna which almost meet mesally. Epimeron with 1 small seta. Presternal area (*prst*, fig. 13, *a*) consisting of 2 sclerites as follows: A small, posterior, median sclerite anteriorly attenuate, 2 setae anteriorly; and a large subtriangular sclerite (comprising the remainder of presternum) striate on anterolateral aspects, with 1 or 2 stout setae near each lateral margin, and anteriorly with 2 short diagonal paramedial rows each of 4 or 5 minute setae. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites with fine shallow punctures more abundant anteriorly, usually with minute setae in punctures; transverse branch of impression reaching about one-fourth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch reaching almost one-half distance from transverse branch to posterior row of

setae. Anterior part of each mediotergite with 4 to 6 unpaired setae (in addition to the minute setae issuing from some of punctures), 1 seta being near middorsal line, 1 at end of transverse branch of impression, 1 within angle formed by branches of impression, 1 laterad to impression, and sometimes 1 or 2 additional small setae between end of transverse impression and seta near middorsal suture. Posterior part of each mediotergite with transverse row of 4 to 7 setae, at least the 2 most medial hairs are paired. Lateral part of mediotergite bears 1 or 2 setae in region between anterior and posterior rows. Anterior laterotergite subtriangular, one-half as large as posterior laterotergite. Episternum bearing 2 fine setae; without spine-like setae. Eusternum with up to 6 fine setae in transverse row anterior to bases of coxae, only 2 to 4 conspicuous. Mesothoracic spiracle slightly larger than spiracles in abdomen; spiracle in first abdominal segment sometimes about same length.

Legs subequal in length. Coxa with up to 28 spinelike setae and 1 or 2 fine setae on anterior aspect, some of spinelike setae noticeably long; a few scattered hairs (some stout) on posterior surface. Trochanter with 6 to 8 spinelike setae on medioanterior surface; 5 to 8 such setae and 1 fine seta on posterior surface; 2 well-developed hairs on medial aspect. Femur about as long and as thick as trochanter; usually with 8 to 10 spinelike setae on medioanterior surface; 3 to 5 spinelike setae and 1 slender seta on posterior surface; 1 or 2 long setae on medial aspect; a few fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 5 or 6 spinelike setae and 1 slender seta on medioanterior surface; 3 to 5 spinelike setae and 1 fine seta on posterior aspect. Ungula more than one-half length of tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth and fifth segments usually widest. Mediotergites (fig. 23, *b*) with small shallow pits; usually with small transverse rugae (or pits) anterior to transverse branches of impressions; transverse branches of impressions (*trim*) reaching to or almost to middorsal sutures on second to eighth segments, shorter on first segment; longitudinal branch of each impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with 5 conspicuous setae, 1 (*atm*) near middorsal suture, usually just caudad to impression, 2 issuing from transverse branch of impression, 1 farther caudad within angle formed by branches of impression, and 1 laterad to impression; usually additional minute setae within impression and in pits and rugae. Posterior part of each mediotergite with transverse

row of 6 to 9 unpaired setae, 4 to 7 long. Sometimes 1 minute seta at posterior end of longitudinal branch of impression. Laterotergite I extending length of segment; bearing 4 to 6 setae. Spiracles usually slightly larger in first abdominal segment, situated in anterior half of segment, in extreme posterior part of subovate spiracular sclerite, which is slightly wider than spiracle and considerably longer. Pleurite well developed, subovate, somewhat diminishing in size from first to eighth segment, with 2 or 3 setae. Sternum of 1 sclerite, subquadrate; impressions very faint, 2 lateral impressions sometimes appearing as pale membranous lines; with about 10 fine setae around margins.

Ninth abdominal segment (fig. 23, *g*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; four-fifths as long as wide; tapering caudally, making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly wrinkled; 4 faint longitudinal impressions, a paramedian pair (*pim*) which converge posteriorly, but do not meet, and 2 laterally (*lim*) which are very indefinite; sometimes with a shallow round depression near center; typically with 4 setae in central area, but highly variable; lateral margins slightly raised and carinate, bearing 3 prominent, blunt setiferous tubercles or "teeth" (*to*); transverse impression (*trim*) continuing completely across segment. Tergite continues uninterrupted laterally and on posterior ventral surface; usually with from 10 to 15 unpaired setae on each side, some issuing from small sclerotized tubercles; anteriorly on lateral aspect 1 or more transverse rows of shallow pits or rugae, usually bearing minute setae. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth total length of segment (exclusive of urogomphi). Pleural area large, transversely striated. Sternum of 2 sclerites, separated anteriorly by medium suture and posteriorly by tenth abdominal segment; each sclerite with 6 to 8 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 23, *g*; fig. 23, *e*) separate, bifid, projecting dorsocaudad; outer prong (*opr*) larger than inner prong. Inner prong (*ipr*) small, projected mediocaudad and sometimes slightly dorsad, terminating in sharp, upturned tip; 1 long seta from lateral aspect and 1 or 2 setae ventrally near base. Outer prong (*opr*) about twice as large as inner prong, corniform, projecting upward with sharp tip curving forward and slightly inward; 2 long setae, 1 from lateral aspect of distal half of prong and 1 from strongly margined

socket on caudolateral aspect of base of prong; 3 or 4 short, fine setae (sometimes minute) scattered over prong, sometimes additional fine setae ventrally or laterally at base of prong. Undivided part of urogomphus with 1 large seta ventrally just anterad to bases of prongs. Caudal notch (*cn*) moderately large, U-shaped, usually slightly longer than wide; sometimes slightly narrowed posteriorly by tips of inner prongs.

Tenth abdominal segment with irregular whorl of about 20 fine setae sometimes arranged in 2 whorls each of about 10 setae; anal aperture linear and median.

Material used in study.—Three examples were examined, including the larval exuvium of one specimen found as an adult in its pupal cell. The adult was identified by W. J. Brown, of Ottawa.

3; Waskesiu Lake, Saskatchewan; Aug. 10, 1937; an adult and its larval skin were found together in the pupal chamber; Robert Glen. (C.N.C.)

LUDIUS RUFOPLEURALIS Fall (?)

FIGURE 23, *c*

Ludius rufopleuralis FALL, Bull. Brooklyn Ent. Soc., vol. 28, p. 188, 1933.

Three unidentified larvae from Fredericton, New Brunswick, bearing strong resemblance to the larva of *nitidulus* (LeConte) have been regarded as *rufopleuralis* Fall or *aratus* (LeConte), the only other North American species included by Brown (1936a, pp. 17-20) in his discussion of the *nitidulus* group.

Both of these species occur in New Brunswick and inhabit the regions of Canada and the United States from the Atlantic seaboard to Lake Superior, with *rufopleuralis* continuing as far west as Winnipeg, Manitoba.

The larvae were found in litter under spruce trees. Cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), were abundant in this litter and it is probable that the larvae were feeding upon these and other insects.

These larvae may be distinguished from the European *nigricornis* (?) by having the outer prongs of urogomphi twice as long as the inner prongs, and from *nitidulus* by the following characters: Nasale and adjoining parts of frons deeply sunken; nasale (fig. 23, *c*) relatively narrow, with tridentate tip, denticles short and narrow and all projecting forward; first prementum with 3 setae just caudad to the base of each palpus, making a transverse row of 6 setae; and basal joint of each labial palpus bearing 2 or 3 setae ventrally. The largest larva examined measured 15 mm. in length, but it was not fully dis-

tended and probably not mature; 3.0 mm. across fourth abdominal segment.

The specimens examined were received through the courtesy of R. E. Balch and are deposited in the Canadian national collection.

LUDIUS NIGRICORNIS (Panzer) (?)

FIGURE 23, *d, f*

Elater nigricornis PANZER, Fauna Insectorum Germaniae Initia, fasc. 61, No. 5, 1799.

Corymbites nigricornis (Panzer), CANDEZE, Monographie des elatérides, vol. 4, p. 159, 1863.

Corymbites (Selatosomus) nigricornis (Panzer), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 379, 1927.

On the basis of adult characters, the European species *nigricornis* (Panzer) has been found by Brown (1936a, pp. 17-19) and other taxonomists to be closely allied to the North American species that constitute the *nitidulus* group. For this reason, two unidentified larvae from Hildesheim and Dresden, Germany, which strongly resemble the known American larvae of this group, have been regarded as larvae of *nigricornis* or of a closely related species.

Nothing is known of the larval habits except that one of these specimens was found burrowing into a mushroom.

The chief distinguishing characters of these larvae are: Urogomphal prongs (fig. 23, *f*) subequal or outer prongs only slightly larger; nasale and adjoining area of frons deeply sunken, nasale being in lowest plane; nasale (fig. 23, *d*) with tridentate tip, all denticles narrow and subrectangular and pointing forward; and presternum of prothorax with posterior median piece reduced to a narrow elongate sclerite about one-half as large as in *nitidulus* (prst, fig. 13, *a*) and in *rufopleuralis* (?). The larger of the two specimens measured 21 mm. in length.

The specimens examined are the property of the British Museum and of Dr. van Emden.

* * *

LUDIUS DIVARICATUS (LeConte)

FIGURES 12, *e*; 24

Corymbites divaricatus LECONTE, ♂, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 446, 1853.

Corymbites crassus LECONTE, ♀, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 440, 1853.

Ludius divaricatus (LeConte), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 427, 1932.

This species is widely distributed in the eastern United States. Leng (1920, p. 170 "*divaricatus* (Lec.)" and "*crassus* (Lec.)") records specimens from Pennsylvania to Georgia and larvae have been taken from as far west as Missouri.

The larvae are soil inhabiting, having been found in bluegrass sod and in clover fields. Blatchley (1910, p. 766) reports finding the adults on the foliage of oak, which location suggests that the typical habitat is woodland meadows. Judging from the date of emergence of reared adults it would appear that pupation occurs normally in early June, much earlier than with most species of *Ludius*. There are no records of this species injuring cultivated crops.

The larva has been described, with good figures, by Jewett (1939). It is the only *Ludius* larva examined in which the sternum of the ninth abdominal segment is of one sclerite. It is also the only *Ludius* combining the characters of a large caudal notch and an undivided presternum of prothorax. Other diagnostic features are found in the urogomphi (*ur*, fig. 24, *c*, *d*), dorsum of the ninth abdominal segment (fig. 24, *d*), nasale (*n*, fig. 24, *a*), mandible (fig. 24, *b*), absence of eyes, absence of impressions on thoracic tergites, and the long impressions on second to fifth abdominal segments. It appears to be an isolated species.

Description of a "mature" larva.—Length 17.0 mm.; greatest breadth 2.7 mm. on fourth abdominal segment; sometimes metathorax and first abdominal segment are widest. A fully distended larva measured 21.5 mm. Jewett (1939, p. 107) records average length as 21 mm. and width 3 mm. across thorax. Body robust; with large membranes on lateral aspect; segments broader than long, eighth abdominal segment sometimes as long as wide; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown or pale brown (near "raw sienna" or "buckthorn brown," Ridgway, 1912); head and ninth abdominal segment slightly darker, mandibles, nasale, talus, and prongs of urogomphi definitely darker; sclerotized parts of venter approximately of same color as dorsum. Dorsum slightly rugose, with a few small shallow pits.

Head short, subquadrangular with arcuate sides, flattened above and below.

Frontoclypeal region (fig. 24, *a*) relatively wide and short; posterior part extending backward to or almost to foramen magnum; truncate posteriorly. Two anterior nasosulcal setae (*nsa*) on each side of base of nasale. Nasale (*n*) well developed, tridentate at tip; median denticle large; acutely pointed when uneroded; lateral denticles small,

sharp, projecting forward from near base of median denticle. Subnasale without denticles or other special sclerotized structures. Paranasal lobes produced beyond nasale; each lobe bearing 3 setae (1 small).

Epicranial plates sparsely and finely punctulate, punctures observable only under high magnification. Dorsal sulci shallow, each with 4 or 5 setae subequally spaced, the most anterior seta being long, the next minute, sometimes wanting, others small. Ventral sulci bearing row of 5 to 7 setae, with 2 to 5 conspicuous. Two large unpaired lateroepicranial setae, sometimes with 1 or more fine, small or minute setae just caudad to each large hair. Eye spot absent; usual eye region bordered by 2 unpaired setae. Postgenal areas expanded mesad, almost meeting; glabrous.

Gula extremely short, narrowed posteriorly by converging postoccipital sutures which almost meet; glabrous.

Antenna with first joint clavate, one-half to two-thirds as wide as long; without setae; 3 to 6 small pores. Second segment subcylindrical, two-thirds as wide as long; two-thirds length of basal segment; 1 or 2 pores; a few small setae borne distally; 1 large conical "sensory" appendix just ventrad to base of third segment. Terminal segment small, barely half as long as second joint and one-quarter to one-third as wide; 4 setae on apex.

Mandibles (fig. 24, *b*) elongate; base narrow, width at ventral aspect of base only one-half total length of mandible; retinaculum (*ret*) relatively small; penicillus (*pen*) short, failing to reach base of retinaculum. Distal half long, inward bending, pointed, somewhat bladelikey with inner margin sharp and slightly convex ventrally, outer margin thickened; dorsal surface flattened or slightly excavate; ventral aspect slightly convex.

Ventral mouthparts about three-fourths to four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines only slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 3 prominent setae on antero-lateroventral aspect. Galea 2-segmented; basal segment with ventral surface usually somewhat flattened, about as long as terminal segment, without setae or pores. Terminal joint narrower than basal segment, 4 to 7 faint pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment as long as wide; distally on mesoventral surface with 1 or 2 small pores and 1 small seta, sometimes additional pores ventrally near center of segment. Second segment longer than wide; longer than first joint and as wide; without setae; 2 or 3 pores. Third

segment almost as long as wide, about one-half length of second segment, bearing 2 to 4 pores ventrally; distally with 1 minute seta on lateral aspect. Fourth joint longer than wide, about as long as third joint, but narrower; 1 pore dorsally. Postmentum with 1 long seta at each corner; a few minute pores scattered along margins. First prementum with 1 large seta just caudad to base of each palpus. Labial palpus with basal segment at least one-half as long as first prementum; longer than wide; with 1 seta ventrally; sometimes 2 or 3 minute pores. Terminal segment shorter and much narrower than basal joint; without setae; usually with 1 or 2 pores.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites with a few small shallow pits; anteriorly with 4 setae, rarely 5 (on each side of median dorsal suture) in transverse row, usually arranged as 1 pair in the middle of the row and the most lateral and most medial setae unpaired, sometimes arranged as 2 pairs with an unpaired seta farther laterad; posterior part of each tergite with 3 setae in transverse row arranged as 1 unpaired lateral seta and 1 pair (1 short, 1 long) farther mediad; tergites glabrous between anterior and posterior rows of setae. Episternum with 1 large seta near center and 1 or 2 minute hairs near presternum. Epimeron bearing 1 small seta. Presternal area consisting of 1 large triangular sclerite; posteriorly acute; anterolateral aspects striate; 1 large seta near each side; anteriorly near midventral line are 2 short oblique rows, each of 3 or 4 minute setae. Eusternum small, membranous or faintly sclerotized; furcal pits well developed. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely and shallowly punctulate; impressions wanting. Anterior part of each mediotergite with 1 moderate-sized seta laterally and usually 10 to 20 very small setae scattered irregularly along anterior margin; posterior part of mediotergite with transverse row of 3 conspicuous setae, 1 near lateral margin and a pair farther mediad; glabrous elsewhere except for minute setae in some of pits. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 10 prominent spine-like setae, usually somewhat scattered, but mostly in 1 row; sometimes also several minute fine setae. Mesothoracic spiracle about equal in size to spiracles in abdomen.

Legs subequal in length. Coxa with up to 25 spinelike setae on anterior aspect; several short stout setae and a few scattered hairs on

posterior surface. Trochanter with 5 to 8 spinelike setae on antero-medial surface; 6 to 12 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 5 to 7 spinelike setae on anteromedial surface; 3 to 7 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; a few fine setae on lateral surface. Tibiotarsus about as long as femur but narrower; 5 or 6 setae around distal margin; 2 or 3 spinelike setae and 1 slender seta on anteromedial surface; 2 or 3 spine-like setae on posterior surface. Ungula when uneroded about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; in material at hand the first segment is widest in some specimens and the fourth segment widest in others. Mediotergites with a few small shallow pits; transverse branches of impressions slightly sinuate, on second to fifth segments reaching middorsal suture, failing to reach the suture on first, sixth, seventh, and eighth segments; longitudinal branch of impression extending one-half to three-fourths distance from transverse branch to posterior transverse row of setae, the length increasing from first to eighth segments. Anterior part of mediotergite bears several minute setae scattered along sclerite, mostly in front of transverse branch of impression; also 3 to 5 small, widely separated, unpaired setae arranged as follows: 1 near medial end of impression (usually slightly caudad to impression), sometimes 1 or 2 toward middle of transverse branch of impression, 1 larger seta farther laterad and caudad (equidistant from transverse and longitudinal branches of impression), and 1 laterally below longitudinal branch of impression. Posterior part of mediotergite with 5 setae in transverse row, arranged as 2 pairs and 1 unpaired hair farther laterad. Sometimes a few additional minute setae observable at high magnifications. Laterotergite I extending length of segment; usually bearing 3 setae. Spiracles subequal; borne in posterior part of very small spiracular sclerite situated in anterior half of segment, directly laterad to transverse branches of impressions on mediotergites. Pleurite well developed, subovate or subtriangular, bearing 2 to 4 setae; size diminishing from first to eighth segments. Sternum of 1 piece, subquadrate, narrower posteriorly, without definite impressions, bearing 6 to 10 conspicuous setae around margins, and sometimes additional minute setae.

Ninth abdominal segment (fig. 24, *c*, *d*), exclusive of urogomphi, shorter than eighth abdominal segment and three-fourths as wide; slightly wider than long; sides of anterior half subparallel, posterior

half tapering caudally making width at anterior margin of caudal notch about two-thirds to three-fourths greatest width of segment. Dorsum convex anteriorly, flatter posteriorly. Dorsal plate (*dpla*) irregularly wrinkled, sometimes with sparse, small, shallow pits some of which usually bear minute setae; 4 indistinct longitudinal impressions, 2 laterally and a paramedian pair; sometimes a short transverse depression in caudal half of segment; central area with 4 prominent unpaired setae; lateral margins not well defined, bearing 2 prominent, blunt, setiferous tubercles or "teeth" (*to*), the more posterior "tooth" being also more ventral; transverse impression (*trim*) continues across segment, almost reaching to pleuron; sometimes few small, stout setae issue from impression and from area in front of impression. Tergite (*tg*) continues uninterruptedly laterally and on posterior ventral surface; usually with about 10 setae on each side. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fourth to one-third total length of segment (exclusive of urogomphi). Pleural area (*pl*) large, transversely striated, sometimes with 1 tiny seta on each side near anterior end. Sternum (*st*) of 1 sclerite, tenth abdominal segment (*10*) emerging from posterior part; bearing many minute setae scattered over sclerite and 6 to 10 larger setae, mostly near margin bordering tenth segment.

Urogomphi (*ur*, fig. 24, *c*, *d*) long, diverging, bifid; outer prong many times larger than inner prong. Inner prong (*ipr*) very small, corniform; appearing as a sharp, horny "tooth" on inner aspect of base of outer prong; projecting caudomedial, at right angle to outer prong; tip usually curving upward; with 2, sometimes 3, prominent setae at base of prong or at junction with outer prong. Outer prong (*opr*) very large, corniform; projecting latero-caudodorsad, curving upward and forward, terminating in sharp, horny point; bearing 1 or 2 prominent setae laterally near base of prong; sometimes a few small or minute setae scattered over proximal part of prong. Undivided part of urogomphus at least three-fourths as long as outer prong; bearing 1 prominent seta ventrally a short distance from junction of prongs; sometimes 1 short seta laterally just anterad to base of outer prong.

Caudal notch (*cn*) large, V-shaped; narrowed posteriorly by inner prongs.

Tenth abdominal segment (*10*) with a whorl of 10 fine setae; anal aperture linear and median.

Material used in study.—Sixteen examples were examined, including eight whole larvae and the exuviae of eight other specimens, which are believed to have been reared. Only five reared adults were located. These were identified by M. C. Lane, of Walla Walla, Wash., and W. S. Fisher, of the U. S. National Museum. The material is from 3 States: Kentucky (13); Clarksville, Tenn. (2); and Cadet, Mo. (1). Reared material for which associated adults are available is listed below.

- 6; Louisville, Ky.; Apr. 29, 1916; all believed to have been reared, but only 3 adults found. (U.S.N.M.; reared adults in W. W. collection, bearing accession numbers 6154, 6155, 6161.)
- 6; Lexington, Ky.; Feb. 17, 1938; 2 reared to adults. This material was received from H. H. Jewett, Agricultural Experiment Station, Lexington, Ky., and is believed to be part of the material used by him in his description of this species. (Larval material in Canadian national collection; adults probably in Experiment Station collection, Lexington.)

* * *

THE LUDIUS CUPREUS GROUP

FIGURES 14, *g*; 25, *a, d, e, g, h*

KEY TO SPECIES

- | | |
|--|-----------------------------------|
| 1. From Europe or Asia..... | 2 |
| From North America..... | kendalli (Kirby) (p. 134) |
| 2. Prongs of urogomphi subequal in length (fig. 25, <i>h</i>)..... | 3 |
| Outer prongs at least twice as long as inner prongs; ¹⁰ central Europe... | virens (Schrank) (p. 133) |
| 3. Not from Denmark..... | 4 |
| From Denmark ¹¹ | pectinicornis (Linnaeus) (p. 131) |
| 4. Mediotergites of abdominal segments (fig. 25, <i>d</i>) usually with moderately coarse pits, especially on each anterior half; each mediotergite of seventh and eighth abdominal segments (fig. 25, <i>d</i>) with posterior transverse row of 7 or more setae; found at altitudes from sea level to several thousand feet..... | cupreus (Fabricius) (p. 126) |
| Mediotergites of abdominal segments usually with smaller pits; each mediotergite of seventh and eighth abdominal segments usually with posterior transverse row of 5 to 7 setae; usually below altitudes of 800 feet..... | pectinicornis (Linnaeus) (p. 131) |

¹⁰ According to Beling (1884, p. 208, "*Corymbites aeneicollis* Olv.").

¹¹ According to Rye (1906, pp. 100-101) *pectinicornis* is the only species of this group inhabiting Denmark.

Knowledge of this group is based upon an examination of larvae of the American species *kendalli* (Kirby), and the European *cupreus* (Fabricius) and *pectinicornis* (Linnaeus) and upon Beling's description of *virens* (Schrank).

These larvae are entirely soil inhabiting. Pupation occurs in an earthen cell in late July or early August. Transformation to the adult state is completed in from 2 to 4 weeks, but the beetle overwinters in its pupal chamber. The larvae of at least two of these species are known to be serious pests of crops for 2 or 3 years after their natural habitat has been brought under cultivation.

The group is very homogeneous and readily distinguished by the combination of extremely small abdominal pleurites (*pl*, fig. 25, *e*) and the presence of spinelike setae on the episterna of the mesothorax and metathorax. Among the known *Ludius* larvae there is no group that is closely related to *cupreus*. Superficial resemblance is found in the larva of *appressus* (Randall), but separation is accomplished readily through the urogomphi (fig. 25, *g, h*), subnasale (fig. 25, *a*), impressions on abdominal segments (fig. 25, *d*), and setation of the episterna of mesothorax and metathorax.

When mature, the larvae usually exceed 20 mm. in length. Dorsum yellowish brown to very dark brown. Caudal notch small, subovate, nearly closed posteriorly. Urogomphi bifid; prongs subequal in length or outer prongs longer (*virens*); inner prong broad, outer prong corniform with sharp tip usually inclined forward. Ninth abdominal segment (fig. 25, *h*) without median dorsal groove; with 2 setae (rarely 4) on central dorsal area; 3 "teeth" (*to*) on lateral margins of dorsal plate; and distance from pleurite to anterior margin of caudal notch approximately one-fifth to one-fourth total length of segment, exclusive of urogomphi. Nasale unidentate. Subnasale (fig. 25, *a*) with transverse row of from 14 to 17 denticles. Frontoclypeal area truncate posteriorly. Eyes present. Gula short, narrow. Mandible robust, much as in *aeripennis* group. Second segment of antenna with 1 "sensory" appendix. Basal segment of labial palpus without setae. Presternum of prothorax divided into 4 sclerites. With few (up to 4) spinelike setae on episterna of mesothorax and metathorax. Mediotergites of abdominal segments (fig. 25, *d*) with transverse branches of impressions reaching from one-half to two-thirds distance from longitudinal branches to middorsal suture and with prominent setae unpaired or semipaired. Sternum undivided in first 8 abdominal segments. Spiracles in anterior half of each segment.

LUDIUS CUPREUS (Fabricius)

FIGURE 25, *a, d, e, g, h*

Elater cupreus FABRICIUS, Species Insectorum, vol. 1, p. 268, 1781.

Ludius cupreus (Fabricius), ESCHSCHOLTZ, in Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.

Corymbites cupreus (Fabricius), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.—SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 359, 1927.

Preserved larvae of the typical *cupreus* and of its color form, *aeruginosus* (Fabricius), were examined. The two forms were found to be indistinguishable. The larva of the typical *cupreus* has been described by Xamheu (1895-1896, pp. 87-88; 1912, pp. 156-160) and by Roberts (1922, pp. 321-323), and the *aeruginosus* larva by Beling (1883, pp. 270-272) and by Saalas (1923a, pp. 125-128).

Saalas (1923a, pp. 128-129) gives a detailed account of the distribution of both forms. These occur widely in temperate and central Europe and are known from several points in Siberia. Only the typical *cupreus* is recorded from Turkestan and Norway, and both are absent from Denmark and Sweden. Both forms are known from the low countries of Holland and Belgium, but Slater (1869, p. 276) indicates that this species prefers higher altitudes, and Xamheu (1912, p. 159) reports specimens occurring at 2,200 meters above sea level.

Roberts (1922, p. 321) describes *cupreus* as a mountain-loving species, common in higher-lying districts of Great Britain and Ireland where the larvae are found in turf and under stones, *aeruginosus* generally being found along with the typical form. Beling (1883, p. 272) reports *aeruginosus* larvae as occurring in forests, preferably in sunny, dry places under moss, and frequently in association with the larvae of *Ludius aeneus* and *Limonium aeneoniger*. Xamheu (1912-1914) found *cupreus* larvae feeding on larval *Aphodius*. Roberts (1922) observed them feeding, in captivity, upon the roots of various plants and considers it probable that the species might cause minor damage in Great Britain. Saalas (1923a) and Linnaniemi (1935) report *aeruginosus* as an important pest of cereal crops in Finland, where it is chiefly encountered in old grassland of clay or sandy loam soils and only to a minor degree in marshy or very sandy soils. Injury is most marked during the first 2 years after grassland has been brought under cultivation.

Because of individual variation, structural characters are not wholly reliable for separating *cupreus* larvae from the very similar larvae of *pectinicornis* and *kendalli*. However, a typical larva of *cupreus* may

be characterized as follows: Up to 25 mm. in length; mediotergites of abdominal segments (fig. 25, *d*) moderately punctate anteriorly; each mediotergite of seventh and eighth abdominal segments (fig. 25, *d*) with posterior transverse row of 7 or more setae; 5 conspicuous setae on antero-lateroventral aspect of stipes.

Description of "mature" larva (form aeruginosus).—Length 21 mm.; greatest breadth 3.0 mm. on fourth abdominal segment. Largest larvae examined measured up to 3.25 mm. in width; Saalas (1923a, p. 125) and Beling (1883, p. 270) report specimens attaining 25 mm. in length. Body robust, with small membranous areas laterally; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown to dark brown, probably near "amber brown" (Ridgway, 1912) or paler in living specimens, but usually much darker in preserved specimens examined; head and prothorax usually slightly darker; Saalas (1923a, p. 126) and Beling (1883, p. 271) state that the ninth abdominal segment is of lighter color; venter somewhat paler than dorsum. Dorsum slightly rugose; segments punctate anteriorly, punctuation varying from few small punctures to many moderate-sized punctures.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 25, *a*) unidentate, terminating sharply when uneroded. Subnasale (*sn*) consisting of transverse ridge, anteriorly convex, finely serrate when uneroded, with from 14 to 17 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small), sometimes additional minute setae.

Epicranial plates sparsely and finely punctulate. Dorsal sulci shallow, each with 5 setae subequally spaced, the most anterior seta very long, the next moderately long, others small. Ventral sulci bearing row of 6 to 9 setae, usually 2 to 5 conspicuous. Two large unpaired lateroepicranial setae. Eye spot black, ovate or circular; bordered by 2 conspicuous setae and sometimes a third minute hair. Postgenal areas expanded mesally, almost meeting; glabrous.

Gula short, narrowed posteriorly; goblet-shaped; glabrous.

Antenna with first segment weakly clavate; two-thirds to three-fourths as wide as long; without setae; 3 or 4 small pores. Second joint subcylindrical, barely as wide as long; three-fifths length of basal segment; 1 or 2 pores; a few minute setae or pegs distally; 1 medium-

sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, barely one-half as long as second joint and about one-fourth as wide; 4 setae on apex.

Mandibles of moderate length, robust, about two-thirds to three-fourths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts at least four-fifths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 5 prominent setae on antero-lateroventral aspect. Galea with basal segment subcylindrical, slightly shorter than terminal segment, without setae or pores; terminal joint narrower than basal segment, outer surface longer than inner surface, 5 to 7 pores on lateroventral aspect. Maxillary palpi with all joints subcylindrical. First joint wider than long; distally on mesoventral surface with group of 5 to 8 small pores and 1 large and 1 small seta, sometimes 1 or 2 additional minute setae. Second segment as long as wide; as long as first joint and three-fourths as wide; without setae; 2 to 4 pores. Third joint almost as long as wide; about one-half length of second segment; with 2 or 3 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral margin. Fourth segment as long as wide; more than one-half length of third joint; without setae or pores. Postmentum with 1 long seta near each corner and sometimes 1 small seta short distance caudad to each long anterior hair; few minute pores. First prementum with 2 large setae just caudad to base of each palpus, making transverse row of 4 hairs. Labial palpus with basal joint cylindrical, about one-half length of first prementum, longer than wide, without setae, with 5 or 6 pores; terminal segment approximately one-half length and less than one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; anterior part of each tergite usually with 6 to 8 setae in transverse row, only 2 most medial setae always paired, others variable, sometimes in semipaired arrangement; posterior part of each tergite usually with 5 or 6 setae in transverse row, 2 most medial setae always paired, 2 most lateral setae often paired or semi-

paired. Episternum with 3 large setae. Epimeron bearing 1 small seta. Presternal area consisting of 4 sclerites as follows: A small posterior medial sclerite, anteriorly attenuate; 2 large, subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout seta laterad to center and a short diagonal row of 5 minute setae on antero-medial aspect; and a very narrow medial anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impressions reaching about one-fourth distance from longitudinal branch to mid-dorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite with transverse row of 3 or 4 unpaired setae. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, 2 most medial paired. Lateral part of each mediotergite with 1 large seta between anterior and posterior rows. Additional minute setae sometimes observable in punctures. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 4 spinelike setae (usually 2 or 3). Mesothoracic spiracles slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa with up to 25 spinelike setae on anterior aspect; 3 to 6 stout setae and a few fine hairs scattered on posterior surface. Trochanter with 6 to 9 spinelike setae on medio-anterior surface; 6 to 8 such setae and 1 fine seta on posterior aspect; 2 well-developed setae on medial surface. Femur usually with 7 to 10 spinelike setae on medioanterior surface; 3 or 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine hairs on lateral surface. Tibiotarsus with 6 setae around distal margin; 3 or 4 spinelike setae and 1 slender seta on medio-anterior surface; 2 or 3 spinelike setae on posterior aspect. Ungula well developed; when uneroded about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 25, *d*) with small shallow punctures, especially in anterior half, usually more pronounced between end of transverse branch of impression and mid-dorsal suture, punctation varying from few small punctures to many moderate-sized pits, usually moderately pitted and becoming stronger from first to eighth segments; transverse branch of impression (*trim*) slightly sinuate, reaching from one-half to two-thirds distance from longitudinal branch to middorsal suture on second to eighth segments, from one-third to one-half distance on first segment; longitudinal

branch of impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with 4 (rarely 5) setae arranged as follows: 1 at end of transverse branch of impression, 1 toward middle of transverse branch, 1 larger seta laterad to longitudinal branch of impression, and another large seta near center of sclerite equidistant from branches of impression; rarely with a minute seta between end of transverse branch of impression and middorsal suture. Posterior part of each mediotergite with transverse row usually of 5 setae on more anterior segments, increasing to between 7 and 10 setae on seventh and eighth segments (sometimes also on sixth and fifth segments); setae not definitely paired, but 4 most medial hairs frequently in semipaired arrangement; in the more posterior segments some of the additional setae are placed between the primary hairs and slightly farther caudad. Laterotergite I (*ltg I*, fig. 25, *e*) extending length of segment, with 3 setae. Spiracles subequal in size, situated in posterior end of subovate sclerite, which is slightly wider than spiracle and 2 to 2½ times as long; in anterior half of segment. Pleurites (*pl*) inconspicuous; reduced to extremely narrow, elongate sclerite usually infolded between laterotergite I and sternum; bearing 1 seta. Sternum (*st*) of 1 piece; subquadrangle; without definite impressions or sutures; several setae along lateral margins, sometimes more abundant in eighth segment.

Ninth abdominal segment (fig. 25, *h*), exclusive of urogomphi, slightly shorter than eighth abdominal segment and three-fourths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flatter posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined; sparsely punctulate anteriorly; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedial pair (*pim*) which converge posteriorly but do not meet; with 2 long setae anteriorly, rarely with 2 small setae farther caudad; lateral margins slightly raised and carinate, bearing 3 prominent blunt setiferous tubercles or "teeth" (*to*); transverse impression (*trim*) usually interrupted in middle, rarely continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 12 to 16 setae on each side, some issuing from small, sclerotized tubercles; anteriorly on lateral aspect with a transverse row, or a confused double row, of conspicuous pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth to one-fourth the total length

of segment (exclusive of urogomphi). Pleural area large, transversely striate. Sternum of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite usually with 5 to 8 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 25, *h*; fig. 25, *g*) robust, separate, bifid; directed caudad; prongs subequal in length but of different shapes. Inner prong (*ipr*) subtriangular, with strongly sclerotized, undate anteromedial margin; projecting mediad or caudomedial, sometimes slightly dorsad, terminating in sharp, horny point; 1 prominent seta issuing from posterior margin, just mediad to base of outer prong. Outer prong (*opr*) corniform; projecting dorsad or caudodorsad with sharp tip curving upward, sometimes slightly forward; 1 prominent seta arising from anterior aspect of base of prong. Undivided part of urogomphus with 1 to 3 setae ventrally and 1 arising from small tubercle just laterad to base of outer prong.

Caudal notch (*cn*) small, subovate; longer than wide; narrowed posteriorly, sometimes closed, by converging inner prongs.

Tenth abdominal segment with about 20 fine setae arranged as 2 equal whorls; anal aperture linear and median.

Material used in study.—Three examples of the typical *cupreus* and 18 of the color form *aeruginosus* were examined. The typical *cupreus* were received from A. W. Rymer Roberts, of Cambridge University, Cambridge, England, and were used by him in preparing his description (1922) of this species. The *aeruginosus* larvae were all from Puolanka and Suomussalmi, Finland (Suomi), and were part of the material used by Prof. U. Saalas in his studies (1923a). The specimens examined are deposited in the Canadian national collection and the U. S. National Museum. Listed below is the material of the typical form that was associated with reared adults. Identification of reared specimens was checked by W. J. Brown, of Ottawa.

2; Windermere, Westend, England; Aug. 5, 1917; 1 reared to adult, Sept. 2, 1918. (C.N.C.)

LUDIUS PECTINICORNIS (Linnaeus)

Elater pectinicornis LINNAEUS, *Systema naturae*, ed. 10, vol. 1, p. 406, 1758.

Ludius pectinicornis (Linnaeus), ESCHSCHOLTZ, in Thon's *Entomologisches Archiv*, vol. 2, p. 34, 1829.

Corymbites pectinicornis (Linnaeus), LATREILLE, *Ann. Soc. Ent. France*, vol. 3, p. 150, 1834.—SCHENKLING, *Coleopt. Cat.* (ed. Junk), vol. 2, pt. 88, p. 361, 1927.

Ludius pectinicornis, a European species, is unique in being the only species of the *cupreus* group to inhabit Denmark. Schiodte

(1870, p. 520) and Henriksen (1911, pp. 260-261) described the larva from that country and Beling (1883, pp. 268-270) from Germany. The larvae are reported to occur in soil in meadows, particularly in woodland meadows. Beling found one larva under moss in a beech grove. According to Slater (1869, p. 276) *pectinicornis* abounds at low altitudes, but decreases at elevations above 800 feet.

Structurally, this larva is virtually indistinguishable from the larvae of *cupreus* and *kendalli*. Minor differences in punctation, setation, and in urogomphi were observed between individuals of these species, but these characters proved to be so variable that when all the available material was examined no clear and constant difference remained. Beling and Henriksen record *pectinicornis* larvae measuring 28 mm. in length. This equals the largest known specimens of *kendalli* and exceeds by 3 mm. the largest *cupreus* larvae reported.

The mediotergites of the first 8 abdominal segments usually have small sparse punctures on each anterior half, the posterior half being less punctate, hence smoother. However, in some specimens the punctation is much coarser and resembles the typical condition found in *cupreus*. In general, setae are somewhat shorter and finer in *pectinicornis* than in *cupreus*; thus where *cupreus* has very small setae, *pectinicornis* usually has still smaller hairs, or, as in some cases, lacks such hairs. The most important setal characters are the following: On each mediotergite of the seventh and eighth abdominal segments, *pectinicornis* larvae have a posterior transverse row of 5 to 7 setae, rarely 8, *cupreus* larvae usually have a row of 7 to 10 setae; on the antero-lateroventral aspect of stipes, *pectinicornis* usually has 4, rarely 5, conspicuous setae, *cupreus* usually has 5 such setae.

Beling (1884, p. 208), in his conspectus, separates the larva of *cupreus* (color form *aeruginosus*) from that of *pectinicornis* on the basis of stronger punctation and rugosity on the mediotergites of the abdominal segments. He distinguishes these species in a similar manner in his detailed descriptions (1883, pp. 269 and 271), but at the conclusion of his description of *pectinicornis* he states (p. 270) (translation): "With the meager research material which has been at my disposal so far, I am forced to leave the question open to doubt as to whether the difference previously mentioned, of wrinkling and pitting on the upper surface of the first eight abdominal segments of the larvae of *Corymbites pectinicornis* and *aeruginosus*, is constant and characteristic to the extent that it could serve for definite distinguishing of the two larvae in question." Saalas (1923a, p. 128) states (translation): "This larva [*cupreus*, form *aeruginosus*] is very simi-

lar to the larva of *Corymbites pectinicornis* except in a few respects; however, in many cases it is very difficult to separate the two larvae with certainty. In the *pectinicornis* larva the hind portions of the abdominal segments are smoother, with only very small, sparse punctures; the inner prongs of the cerci [*urogomphi*] are directed more posteriorly making the angle between the two prongs more acute than in *aeruginosus*, almost right-angled, in *aeruginosus* more obtuse. The larva of *pectinicornis* has, on the hind margins of the inner prongs, only a very small, almost indiscernible tubercle, in the larva of *aeruginosus* the tubercle is usually somewhat larger and broader."

In the present study, similar differences were observed in individual cases, but these characters were found to vary and to intergrade so much that no reliance could be placed upon them as specific characters.

Material used in study.—Eight larvae, six from Denmark and two from Finland (Suomi), were examined. These specimens formed part of the material available to Henriksen (1911) and Saalas (1923a) in their studies on this species. To the writer's knowledge, none of the material was associated with reared specimens. The larvae examined are deposited in the Canadian national collection, the Royal Veterinary and Agricultural College, Copenhagen, and the U. S. National Museum.

LUDIUS VIRENS (Schrank)

Elater virens SCHRANK, Schriften Berlinischen Gesell. naturf. Freunde, vol. 2, p. 317, 1781.

Elater aeneicollis OLIVIER, Journ. Hist. Nat., vol. 1, p. 264, 1792.

Corymbites virens (Schrank), HAROLD, Coleopterologische Hefte, vol. 5, p. 92, 1869.—SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 363, 1927.

Larvae of this central European species were not available for examination in the present study and the remarks that follow are adapted from the writings of Beling (1883, pp. 265-268; 1884, p. 208), who described the larva under the name *aeneicollis* Olivier.

Larvae, apparently identified through rearing, were collected by Beling from moist soil under moss in the forests of Germany, beech and pine forests being mentioned specifically. According to his observations the larvae were confined to areas covered by deposits of century-old ore slag. Such areas were kept moist by nearby springs, but, as a rule, the vegetation was limited to mosses and a few characteristic flowering plants.

Ludius virens is readily separated from the other known larvae of the *cupreus* group by having the outer prongs of the urogomphi at least twice as long as the inner prongs. It also attains a greater length, reaching 30 mm.; width 3 mm. Dorsum very dark brown (black-

brown) ; venter reddish yellow or brownish yellow. Mediotergites of first 8 abdominal segments with moderately coarse punctures anteriorly, smoother posteriorly, thus resembling the typical sculpture of *cupreus* larvae. Ninth abdominal segment with sharp, elevated sides each bearing 3 short, sharp teeth of which the 2 most anterior are closer together and the middle tooth usually largest. Urogomphi bifid. Outer prongs pointed, directed upward and curving forward. Inner prongs broader, one-half (or less) as long as outer prongs, projecting toward each other. Caudal notch elliptical, longer than wide, posterior opening about one-third greatest width of sector.

LUDIUS KENDALLI (Kirby)

FIGURE 14, g

Ctenicerus kendalli KIRBY, in Richardson's Fauna Boreali-Americana, vol. 4, p. 149, 1837.

Elater anchorago RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 5, 1838.

Ludius virens of American authors, nec Schrank.

Ludius kendalli (Kirby), BROWN, Canadian Ent., vol. 71, p. 44, 1939.

Ludius kendalli is the only North American species belonging to the *cupreus* group. Larvae have been identified through rearing of both the typical form and an unnamed color form, the adult of which has the elytra entirely purplish.

According to Brown (1939, p. 44) the range of this species "is transcontinental, and extends from the northern limits of the sub-arctic forests south to Maine, the Lake Superior region, the prairies, and central British Columbia." Larvae have been collected in the north-central parklands of Saskatchewan, the typical and the darker forms occurring together. The larvae live in the soil and are most abundant in native grassy areas bearing a growth of young willow. This species causes severe injury to garden and field crops for about 3 years after such areas are brought under cultivation. The species has not been taken from the open prairie regions of the Prairie Provinces.

In structure, *kendalli* is very similar to the larvae of *cupreus* and *pectinicornis*; hence identification is much more readily achieved on the basis of distribution.

Full-grown larvae measure up to 28 mm. in length and 3.75 mm. in greatest width. In the typical *kendalli*, the dorsum is usually yellowish brown, somewhat paler than in most *cupreus* larvae; in the unnamed color form the dorsum is darker, being similar in color to most *cupreus*. As in *pectinicornis*, the mediotergites of the first 8

abdominal segments bear sparse, small punctures, rarely as punctate as in the majority of *cupreus* larvae. In agreement with *cupreus*, each mediotergite on the seventh and eighth abdominal segments usually bears 7 or more setae in the posterior transverse row, and the stipes usually have 5 conspicuous setae on the antero-lateroventral aspect. Urogomphi (fig. 14, *g*) as figured.

Material used in study.—Examination was made of 29 specimens, including the larval exuviae of 5 reared specimens. The reared adults were identified by W. J. Brown, of Ottawa. All material is in the Canadian national collection. Specimens associated with reared adults are listed below:

- 3; Spalding, Saskatchewan; July 9, 1927; 1 reared; N. J. Atkinson.
 5; Spalding, Saskatchewan; June 19, 1930; 2 reared; R. Glen.
 13; Naicam, Saskatchewan; July 8, 1930; 2 reared; Albert Johnson.

* * *

LUDIUS APPRESSUS (Randall)

FIGURES 14, *a, b*; 25, *b, c, f*

Elater appressus RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 11, 1838.

Corymbites appressus (Randall), LeCONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 446, 1853.

Ludius appressus (Randall), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 420, 1932.

The distribution of this rather rare North American species is given by Van Dyke (1932, p. 396) as "Lake States to Nova Scotia and Maine." The only larvae known were collected from decomposing litter under spruce in Quebec and New Brunswick. Larvae of this species were observed by R. F. Morris, of Fredericton, New Brunswick, to feed upon the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig). One specimen that was reared to maturity transformed to the adult stage during August.

The brief description that follows was first prepared from the badly broken larval skin of the reared specimen. Subsequently it was checked by examination of whole larvae.

Ludius appressus is not closely allied to any of the known species of *Ludius*, but the larva bears superficial resemblance to those of the *cupreus* group. Separation is secured through differences in urogomphi (fig. 25, *c, f*), subnasale (fig. 25, *b*), and setation of episterna of mesothorax and metathorax.

Larva brown, unicolorous; dorsum punctulate or sparsely punctate, pits shallow. Probably attaining or exceeding 20 mm. in length when

full grown. Caudal notch small, ovate. Urogomphi bifid; prongs rather short, subequal in length and sharply pointed; inner prong (*ipr*) with a strongly sclerotized protuberant inner margin. Three small rounded "teeth" on each lateral margin of dorsal plate of ninth abdominal segment. Nasale (*n*, fig. 25, *b*) of 1 pointed tooth. Subnasale (*sn*) with 1 large central tooth and numerous fine denticles laterally. One "sensory" appendix on second segment of antenna. Mandible short, robust; distal half with prominent expansion of dorsal margin of inner surface. Gula short and relatively narrow. Eyes present. Frontoclypeal region extending backward to foramen magnum; truncate posteriorly. Prosternum divided into 4 sclerites. Without spinelike setae (rarely with 1 seta) on episterna of mesothorax and metathorax. First 8 abdominal segments with short impressions, transverse branches reaching one-fourth to one-third of distance from longitudinal branches to middorsal suture; prominent setae unpaired; pleurites very small (as in fig. 25, *e*) and usually difficult to observe; sternum undivided; spiracles subequal in size and situated in anterior half of each segment.

Material used in study.—Three specimens, two larvae from New Brunswick and the last larval exuvium of a reared specimen, were examined. The reared adult was identified by W. J. Brown, of Ottawa.

1; Cascapedia River, Quebec; Aug. 26, 1935; reared to adult; M. L. Prebble. (C.N.C.)

* * *

LUDIUS RESPLENDENS AERARIUS (Randall)

FIGURES 11, *b*, *f*; 13, *b*; 26

Ludius resplendens ESCHSCHOLTZ, in Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.

Elater aerarius RANDALL, Boston Journ. Nat. Hist. vol. 2, p. 7, 1838.

Diacanthus racinei CHEVROLAT, Rev. Mag. Zool., p. 578, 1852.

Corymbites viridis GERMAR (nec Say), Zeitschr. für die Ent., vol. 4, p. 61, 1843.

Ludius resplendens aerarius (Randall), BROWN, Canadian Ent., vol. 71, p. 45, 1939.

In addition to the typical *resplendens*, Brown (1939, p. 45) recognizes two subspecies, *breweri* (Horn) and *aerarius* (Randall). Combining the information given by Brown, Leng (1920, p. 169) and Van Dyke (1932, p. 425), the distribution is as follows: the typical *resplendens* is found along the mountains from Alaska to California; at its southern limits it is replaced by *breweri* and along the mountains of western Alberta it intergrades with the eastern *aerarius*,

which continues through to the New England States, eastern Canada, and Newfoundland.

Larvae of *resplendens aerarius* (Randall) have been collected in Alberta, Saskatchewan, and Manitoba. The other forms of the species are not known in the larval stage. All remarks that follow apply only to the subspecies *aerarius*.

The larvae inhabit wooded areas, apparently being present in practically every well-established poplar bluff in the Prairie Provinces, as well as in all extensive forests. Specimens have been taken from decaying stumps and logs of poplar, willow, and pine, but are usually more abundant in the leaf litter beneath such trees. The species is obtained occasionally from native shrub thickets. In the late autumn, larvae have been found in the soil, just under the litter, probably in preparation for hibernation.

The species is not known to be of economic importance. In captivity a larva was observed to attack and partially devour a cutworm. A wood-feeding habit is also suggested from finding in a fresh burrow in a chip of wood a larva with its head at the blind end of the tunnel. Pupation and ecdysis usually take place in cells made in wood. The pupa appears in late July and, under laboratory conditions, transforms to the adult in about 12 days. All adults found in late autumn were in twigs, logs, and stumps, many still within their pupal chambers.

In structure, the larva of *resplendens aerarius* exhibits fundamental *Athous* and *Elathous* characters, but does not fall in any known "species group." It is most readily identified by the ninth abdominal segment (fig. 26, *f*), especially by the blunt outer prongs of urogomphi (*opr*, fig. 26, *e*, *f*), the small caudal notch (*cn*), the median dorsal groove (*mg*), and the blunt "teeth" (*to*) on the margins of the dorsum. Valuable supplementary characters are the yellow-brown color; the abdominal mediotergites (fig. 26, *c*) with long impressions, but lacking other prominent sculpture; the presence of eyes; tridentate nasale (fig. 26, *a*); shape of the base of the ungula (fig. 26, *d*); and the presence of several minute setae just behind the large anterior seta in each dorsal head sulcus (fig. 26, *b*).

Description of "mature" larva.—Length 21 mm.; greatest breadth 2.75 mm. on fourth abdominal segment. Fully distended larvae measured up to 23 mm. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown (near "amber brown," Ridgway, 1912), mesothorax, prothorax, and head somewhat darker, mandibles, nasale, talus, and prongs of urogomphus considerably darker; venter slightly paler,

except on head. Dorsum slightly rugose, with scattered, small, shallow pits.

Head subquadrangular, with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 26, *a*) of 1 well-developed tooth extending from one-half to three-fourths as far forward as paranasal lobes, terminating in 3 subequal denticles, lateral denticles projecting anterolaterad; sometimes eroded to appear as a single blunt tooth. Subnasale (*sn*) consists of many fine, sharp, forward-projecting denticles on basal part of nasale; sometimes 50 or more such denticles, but number highly variable; frequently much eroded. Paranasal lobes produced beyond nasale, each bearing 3 or more setae (only 2 prominent).

Epicranial plates sparsely and finely punctulate. Dorsal sulci (fig. 26, *b*) each with 1 very long anterior seta followed by a scattered group of 2 to 7 extremely minute setae (usually 4 or 5), 1 of which is always found just laterocaudad to the large anterior hair; in posterior part of sulcus are 3 small, subequally spaced setae. Ventral sulci with row of 7 to 10 setae, usually about 4 conspicuous. Two long unpaired lateroepicranial setae. Eye spot black, well defined, ovate or circular; surrounded by 3 or 4 setae, only 2 conspicuous. Postgenal areas expanded mesally, almost meeting, usually with 1 minute seta centrally located.

Gula short, narrowed posteriorly by converging postoccipital sutures, goblet-shaped, glabrous.

Antenna with first joint weakly clavate, two-thirds to three-quarters as wide as long; without setae; 2 or 3 small pores. Second segment subcylindrical, two-thirds to three-quarters as wide as long; about three-fifths length of basal joint; 1 or 2 pores; a few minute setae or pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, at least half as long as second joint and about one-third as wide; 4 setae and some "sensory" pegs on apex.

Mandible of moderate length, robust; two-thirds to three-fourths as wide at base (on ventral aspect) as long; retinaculum very well developed, more than one-third length of distal half of mandible; penicillus present, sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short, deep, dorsal groove; inner face slightly excavate with small median carina,

ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts from three-fourths to four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines only slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-latero-ventral aspect. Galea with basal joint subcylindrical, shorter than terminal segment, without setae or pores; terminal joint about as wide as basal joint, outer aspect longer than inner aspect, 2 or 3 pores on lateroventral surface. Maxillary palpi with all joints subcylindrical. First segment slightly wider than long, with ventral surface shorter than other surfaces; distally on mesoventral surface with group of 3 or 4 small pores and 2 setae; 1 or 2 pores near middle of ventral aspect. Second segment nearly as long as wide; as long as first segment and almost as wide; without setae; 1 or 2 pores. Third joint about as long as wide; at least one-half length of second joint; two pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment longer than wide; about as long as third joint; 1 minute seta on dorsal surface. Postmentum with 1 long seta at each corner; 1 small seta short distance caudad to each long anterior hair; minute pores and sometimes 1 or 2 additional small setae along lateral margins. First prementum with 1 large and 1 small seta just caudad to base of each palpus, forming transverse row of 4 hairs. Labial palpus with basal joint about one-half as long as first prementum, as long as wide, without setae, 3 or 4 pores; terminal segment about three-fourths length and one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; without well-defined impressions, but each tergite with narrow pale line (sometimes branched) beginning near middle of middorsal suture and running cephalolaterad across about one-third of tergite; anterior part of each tergite with about 9 prominent setae in transverse row, usually arranged as 3 pairs and 3 unpaired hairs, the most lateral seta usually unpaired; posterior part with 5 or 6 prominent setae in transverse row, arranged as 3 pairs or 2 pairs and 1 unpaired; glabrous elsewhere except for few minute setae issuing from some of punctures. Episternum with 3 conspicuous setae. Epimeron bearing 1 small seta. Presternal area of 1 large, triangular sclerite, posteriorly acute; striate on antero-

lateral aspects; 1 stout seta near each lateral margin and anteriorly near midline with 2 short rows each with 4 or 5 minute setae; a short sclerotized rod appears on the median line about one-fourth distance from anterior margin. Eusternum small, usually definitely sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression reaching from one-fourth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from some of punctures. Posterior part of each mediotergite with transverse row of 3 to 6 setae; usually only 3 large, 2 of which are paired. One or 2 large unpaired setae and sometimes 1 small seta along margin of each mediotergite, laterad to impression. Anterior laterotergite subtriangular, almost as large as subovate posterior laterotergite. Episternum bearing up to 7 spinelike setae, usually from 3 to 5. Mesothoracic spiracle slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa with up to 43 (usually about 30 to 35) spinelike setae on anterior aspect, usually a few less on prothoracic legs than on other legs; 4 to 8 stout setae and a few fine hairs on posterior surface. Trochanter with 8 to 12 (1 specimen with 16) spinelike setae on medioanterior surface; up to 12, rarely more, such setae and 1 fine seta on posterior surface; 2 to 4 well-developed setae on medial aspect. Femur usually with 7 to 12 (1 specimen with 14) spinelike setae on medioanterior aspect; 4 to 6 spinelike setae and 1 slender hair on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae laterally. Tibiotarsus with 6 setae around distal margin; 2 to 5 spinelike setae and 1 slender seta on medioanterior surface; 2 to 4 spinelike setae on posterior aspect. Ungula (*un*, fig. 26, *d*), when uneroded, about three-fourths as long as tibiotarsus; base expanded medially with distal end pointed (when uneroded) giving ungula appearance of bottle opener.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 26, *c*) with scattered, small, shallow pits; transverse branch of impression (*trim*) variable, but usually reaching to or almost to middorsal suture on segments 2 to 5, shorter in other segments, especially in first segment where it attains only about one-half distance to middorsal suture; longitudinal branch of impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior

transverse row of setae. Anterior part of each mediotergite without prominent setae, but sometimes with a few minute hairs issuing from punctures and from transverse branch of impression. Posterior part of each mediotergite with 6 long setae (only 4 in first segment) arranged as 3 pairs, sometimes with 2 or 3 small unpaired setae distributed between the pairs. One prominent seta and sometimes additional minute hairs laterad to midpoint of longitudinal branch of impression. Laterotergite I extending length of segment; 3 setae, only 1 long. Spiracles subequal; spiracular sclerite ovate, about twice as wide as spiracle and 2 to 3 times as long, situated in anterior half of segment. Pleurite well developed, subovate; decreasing in size from first to eighth segments, being only about one-half as large in eighth; with 1 large and 1 small seta. Sternum of 1 sclerite, subquadrate; impressions very faint; usually 8 to 10 unpaired setae near margins.

Ninth abdominal segment (fig. 26, *f*), exclusive of uprogomphi, slightly shorter than eighth abdominal segment and at least three-fourths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about three-fifths greatest width of segment. Dorsum convex, somewhat flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sometimes with a few small, shallow, indefinite pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedian pair (*pim*) which converge posteriorly and meet to form a short median groove (*mg*) almost in center of dorsal plate; without setae (rarely 1 or 2 very small hairs) except at lateral margins which are slightly raised and carinate, bearing 3 prominent blunt setiferous "teeth" (*to*) (a fourth "tooth" lies farther posteriorly and more ventrally); transverse impression (*trim*) continues across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface, usually with from 10 to 14 setae on each side, but number highly variable, some issuing from small sclerotized tubercles; anteriorly on lateral aspect about a dozen conspicuous punctures. Distance between posterior margin of pleural area and anterior margin of caudal notch about one-fifth to one-fourth total length of segment (exclusive of urogomphi). Pleural area large, transversely striate except for small ovate sclerite at each anterior end. Sternum of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite usually with from 5 to 8 setae, mostly in row near tenth abdominal segment.

Urogomphi (*ur*, fig. 26, *f*; fig. 26, *e*) separate, bifid; projecting caudad or dorsocaudad; prongs subequal in length. Inner prong (*ipr*) broad, much stouter than outer prong; directed caudomedial; heavily sclerotized along anteromedial margin; bearing 2 long unpaired setae, 1 on caudolateral aspect near junction with outer prong, other slightly farther ventrad. Outer prong (*opr*) subcylindrical, narrowing toward tip, which is bluntly rounded; usually slightly shorter than inner prong; projected caudodorsad, usually slightly laterad; prominent tubercle ventrolaterally at base of prong; with 2 large setae, 1 on anteromedial aspect, about halfway along prong, other arising from upper aspect of base of tubercle. Undivided part of urogomphus broad, with prominent seta ventrally near base.

Caudal notch (*cn*) small, subcircular, almost closed by converging inner prongs.

Tenth abdominal segment with whorl of 10 fine setae and usually additional smaller hairs; anal aperture linear and median.

Material used in study.—Forty-two examples, including the exuviae of five reared specimens, were examined. One larva was collected at Elkwater Lake, Alberta; the others were all collected in Saskatchewan. W. J. Brown, of Ottawa, identified the reared adults. All material is in the Canadian national collection. The following notes refer to separate collections for which there are associated reared adults.

9; Saskatoon, Saskatchewan; June 21, 1930; 3 adults emerged July 28, July 29, Aug. 1, respectively; R. Glen.

3; Cypress Hills, Saskatchewan; July 18, 1935; 2 adults emerged Aug. 4 and Aug. 8; R. Glen.

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LUDIUS SJAELANDICUS (Müller)

FIGURES 14, *f*; 27

Elater sjaelandicus MÜLLER, Fauna Insectorum Friedrichsdalina, p. 21, 1764.

Elater tessellatus FABRICIUS (nec Linnaeus), Systema Eleutheratorum, p. 211, 1775.

Corymbites tessellatus (Fabricius), CANDEZE, Monographie des elatérides, vol. 4, p. 104, 1863.

Corymbites sjaelandicus (Müller), SCHIODTE, Naturh. Tidsskr., ser. 3, vol. 3, p. 554, 1865.

Corymbites (Actenicerus) sjaelandicus (Müller), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 368, 1927.

Ludius sjaelandicus (Müller), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 391, 1932.

This species is well known in northern and central Europe and in Siberia. According to Leng (1920, p. 169) and Van Dyke (1932,

p. 391) *sjaelandicus* also inhabits the northeastern part of North America, but no larvae have been obtained from this region.

Larvae have been collected from rotten birch, sphagnum, and cow dung, but the typical habitat is the moist soil of low-lying land such as peat moors, alder swamps, grassy meadows, and damp, moss-covered parts of forests. Injury to domestic plants frequently results when such areas are brought under cultivation. Durnovo (1935) reports this species as a pest of vegetables on peaty soil recently cleared of alder. He further states that the larvae are much less numerous in clayey soils and practically absent from sandy areas. Pupation occurs in late July or early August.

The larva has been described from Denmark by Schiodte (1870, p. 521) and Henriksen (1911, pp. 261-262), and from Germany by Beling (1883, pp. 272-273, "*tessellatus* L."). It is readily recognized by having the spiracles situated in the posterior half of the eighth abdominal segment (*sp*, fig. 27, *d*), but not enlarged as in the *pyrrhos* group. The larva is further characterized by its bright yellow color; tridentate nasale (*n*, fig. 27, *a*); presternum of prothorax divided into 3 parts; ninth abdominal segment (fig. 27, *c*, *d*) with small caudal notch (*cn*), urogomphi (*ur*) bifid with inner prongs (*ipr*) slightly longer and much more robust than outer prongs (*opr*), 2 setae on central dorsal area, and 3 prominent blunt teeth (*to*) on lateral margins of dorsum.

Description of "mature" larva.—Length 22 mm.; greatest breadth 3.0 mm. on fourth and fifth abdominal segments. Henriksen (1911, p. 262) and Beling (1883, p. 272) record specimens measuring 26 mm. in length. Body robust; with moderately large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about three-fourths greatest body width. Dorsum bright yellow (near "hazel" or slightly darker than "ochraceous buff," Ridgway, 1912); mandibles, nasale, talus, and prongs of urogomphi darker; venter slightly paler. Dorsum shiny; slightly rugose; with a few small and very shallow inconspicuous pits.

Head subquadrangular with arcuate sides, about as thick at base as long; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 27, *a*) with tip tridentate when uneroded; median denticle largest, lateral denticles projecting anterolaterad. Subnasale (*sn*) consisting of strongly sclerotized transverse ridge with large, forward-projecting

median denticle; finely serrate (when uneroded) on each side of median tooth. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates nearly smooth. Dorsal sulci shallow, each with 4 setae subequally spaced, the most anterior seta being very long; others very small, somewhat peglike. Ventral sulci bearing row of 2 to 4 setae, only 1 or 2 conspicuous. Two large unpaired latero-epicranial setae. Eye spot black, well defined, ovate or circular; bordered by 2 prominent setae. Postgenal areas expanded mesad, almost or actually meeting.

Gula (*gu*, fig. 27, *b*) short, greatly narrowed (sometimes obliterated) in the middle by converging postoccipital sutures; glabrous.

Antenna with first joint clavate, one-half to three-fifths as wide as long; without setae; 7 to 9 small pores. Second joint subcylindrical, slightly more than one-half as wide as long; two-thirds length of basal joint; 1 or 2 pores; a few minute setae borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-third as long as second segment and one-quarter as wide; 4 setae on apex.

Mandible of moderate length, robust; ventrally, about two-thirds as wide at base (ventral aspect) as long; retinaculum very large; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with shallow dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and more strongly convex dorsally.

Ventral mouthparts three-fourths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated; without seta between rami of Y-shaped brace. Stipes large, subrectangular; proxistipes and dististipes not distinct; with 2 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, about as long as terminal joint, without setae or pores; terminal segment narrower than basal segment, with 4 to 6 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint almost as wide as long; distally on mesoventral surface with group of 3 to 5 small pores; without setae. Second segment almost twice as long as wide; longer than first segment and as wide; without setae; with 3 or 4 pores. Third segment almost as long as wide; one-half or less length of second segment; without setae; with 2 or 3 pores ventrally. Fourth segment slightly longer than wide; almost as long as third segment; without pores or setae. Postmentum with 1 long

seta at each corner. First prementum with 1 large seta just caudad to base of each palpus. Labial palpus with basal joint at least one-half length of first prementum, longer than wide, without setae, with 5 or 6 pores; terminal joint about one-half length and less than one-half width of basal segment, without setae, usually with 1 pore.

Prothorax nearly equal to combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites slightly rugose, with few small and very shallow pits; anteriorly with 2 pairs large setae (on each side of median dorsal suture) in transverse row; posteriorly with 4 prominent setae in transverse row, only 2 most medial setae paired; glabrous elsewhere. Episternum with 1 large seta. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: A small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites (sometimes partially fused) striate on anterolateral aspect, with 1 stout seta laterally and a diagonal row of 4 or 5 minute setae on anteromedial aspect. Eusternum small, usually with narrow medial sclerite. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites with few small and very shallow pits; transverse branch of impression reaching about one-fourth distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite with 1 or 2 minute setae laterad to impression. Posterior part of mediotergite with 4 conspicuous setae in transverse row, only the 2 most median setae paired. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing from 2 to 6 short spinelike setae. Eusternum without transverse row of setae.

Legs rather short, strong. Coxa with up to 25 spinelike setae on anterior aspect, mostly in 2 oblique rows diverging mesally with conspicuous glabrous area between rows; 7 to 8 stout setae on posterior surface. Trochanter with 10 to 12 spinelike setae on medioanterior surface, arranged in 2 rows; 6 to 9 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 9 to 11 spinelike setae on medioanterior surface; 4 to 6 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus about as long as femur, but narrower; with 5 or 6 setae around distal margin; 4 spinelike setae and 1 slender seta on medioanterior surface; 3 or 4 spinelike setae on posterior surface. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (*mtg*, fig. 27, *d*) with few small, shallow pits; transverse branch of impression (*trim*) shallow, slightly sinuate, on second to eighth segments reaching from one-half to three-fourths distance from longitudinal branch to mid-dorsal suture, shorter on first segment; longitudinal branch of impression shallow, variable in length, extending from one-half to nearly total distance from transverse branch to posterior transverse row of setae. Anterior part of mediotergite without setae. Posteriorly on each mediotergite, transverse row of 5 setae on second to eighth segments, only the most lateral seta being unpaired; only 3 setae in posterior row on the first abdominal segment. Usually 1 small seta, rarely 2, along margin of mediotergite laterad to impression. Spiracles (*sp*, fig. 27, *d*) subequal in size, in anterior half of segment except in eighth abdominal segment where spiracle always in posterior half. Spiracular sclerite (*spsc*) well developed, subovate; usually wider than spiracle and 2 to 3 times as long as spiracle, increasing in size from first to seventh segment, smaller in eighth segment. Laterotergite I (*ltg I*) extending length of segment; 1 large seta on dorsal margin. Pleurite large, subovate, with 1 large seta. Sternum of 1 piece, subquadrate; 4 faint impressions, indefinite except on the more anterior segments; with 1 stout seta at each corner.

Ninth abdominal segment (fig. 27, *c, d*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch two-thirds (or less) greatest width of segment. Dorsum convex, more pronounced anteriorly. Dorsal plate (*dpla*) sloping downward from front to back, usually with a short transverse concavity slightly caudad to the 2 setae found near the middle of the plate; irregularly lined and wrinkled, but without pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a short paramedian pair (*pim*) in anterior part of plate; lateral margins slightly raised and carinate, bearing 3 prominent blunt "teeth" (*to*), each with a long bristle; transverse impression (*trim*) feeble, usually interrupted in middle. Tergite (*tg*) continues uninterrupted laterally and on posterior ventral surface; usually with from 5 to 10 unpaired setae on each side, some issuing from small sclerotized tubercles. Distance between posterior margin of pleural area (*pl*) and anterior margin of caudal notch from one-sixth to one-fifth of total length of segment (exclusive of urogomphi). Pleural area well developed, membranous, transversely striate. Ster-

num of 2 sclerites, separated anteriorly by median longitudinal suture, and posteriorly by tenth abdominal segment; each sclerite with 2 or 3 setae in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 27, *c*, *d*) separate, robust, bifid; inner prong slightly longer and much more robust than outer prong. Inner prongs (*ipr*) short, stout, with hard, dark anteromedian margins; directed inwardly; tips bluntly pointed, frequently meeting or overlapping; each with 2 stout setae, 1 issuing from base of small tubercle on caudolateral margin and 1 from midventral surface. Outer prongs (*opr*) shorter and more slender than inner prongs, projecting upward, sometimes slightly outward and backward; each terminating in horny tip, sometimes with short, sharp point inclined inward; 2 large setae, 1 on anteromedial surface of distal half of prong, the other at base of prong on lateroventral aspect. Undivided part of urogomphus short and very broad, with 1 stout seta ventrally just anterad to bases of prongs.

Caudal notch (*cn*) small, subovate or shield-shaped, slightly longer than wide; very narrow posteriorly, often entirely closed by converging inner prongs.

Tenth abdominal segment (*10*) surrounded by 10 prominent setae; anal aperture linear and median.

Material used in study.—Fourteen larvae were examined. These were collected from Denmark (6), Finland (5), and Germany (3). So far as is known, none of these specimens were collected at the same time and place as specimens that subsequently were reared, but the larva of this species has been known to European workers for many years and it is believed that the material is reliably named. The material examined is deposited in the Canadian national collection, the U. S. National Museum, and van Emden's collection.

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THE LUDIUS PYRRHOS GROUP

FIGURES 11, *e*; 28

KEY TO SPECIES

From eastern North America.....*pyrrhos* (Herbst) (p. 148)
From western North America.....*protractus* (LeConte) (p. 149)

Knowledge of this group is limited to rather inadequate larval material of *pyrrhos* (Herbst) and *protractus* (LeConte). The group differs from all other known *Ludius* larvae in the character of the spiracles of the eighth abdominal segment (figs. 11, *e*; 28, *a*), which

are at least twice as long as the spiracles in the other abdominal segments and situated much farther caudad. Other important diagnostic features are found in the nasale (fig. 28, *c*), which is tridentate at tip with small median denticle, and in the mandible (fig. 28, *b*) with its unusually robust distal half. The group is not closely allied to any other of the known *Ludius* larvae.

Larvae of the *pyrrhos* group are yellowish brown, exceeding 20 mm. in length when full-grown. Dorsum punctulate. Caudal notch small, almost closed posteriorly. Urogomphi bifid, prongs subequal in length; inner prong broad; outer prong less robust, terminating in moderately blunt point. Dorsum of ninth abdominal segment (fig. 28, *d*) with 2 unpaired setae, and sometimes with faint short median groove; anterior margin of dorsal plate well defined throughout; 3 rounded "teeth" (*to*), sometimes with pointed tips, on lateral margins of dorsum. On ninth abdominal segment the distance between the pleural area and caudal notch equals one-quarter to one-third of entire length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. One "sensory" appendix on second segment of antenna. Second joint of maxillary palpus longer than first joint. Eyes present, 2 prominent unpaired setae around each eye. Epicranial plates each with 2 prominent unpaired lateroepicranial setae. Gula short and very narrow. Presternum of prothorax of 1 piece, but deeply incised on lateroposterior aspects, almost resulting in a separate small median piece posteriorly. Without spinelike setae on episterna of mesothorax and metathorax. Mediotergites of mesothorax and metathorax with definite impressions. Mediotergites of abdominal segments (*mtg*, fig. 28, *a*) with transverse branches of impressions (*trim*) failing to reach middorsal suture and with a posterior transverse row of 5 prominent setae arranged as 2 pairs with 1 unpaired hair farther laterad.

LUDIUS PYRRHOS (Herbst)

FIGURES 11, *e*; 28

Elater pyrrhos HERBST, *Natursyst. Ins. Käfer*, vol. 10, p. 30, 1806.

Corymbites pyrrhos (Herbst), LECONTE, *Trans. Amer. Philos. Soc.*, new ser., vol. 10, p. 447, 1853.

Ludius pyrrhos (Herbst), VAN DYKE, *Proc. California Acad. Sci.*, vol. 20, p. 394, 1932.

The larval material of this species that was available for study was not adequate for a description of greater detail than that given under the *pyrrhos* group.

The third segment of the antenna is very short, apparently being less than one-half as long as the second segment. This might be a specific character. At present, the separation of the larvae of *pyrrhos* and *protractus* is best made on the basis of geographical distribution.

Apparently the material examined was part of a collection made in a cornfield that was damaged by wireworms. This is the only information available on the biology of the species.

Material used in study.—According to the ledger records of wireworm rearing at the United States Bureau of Entomology Laboratory, Hagerstown, Md., specimens given the accession numbers 6066 to 6080, inclusive, were collected together at College Park, Md., April 24, 1916, and were identified, probably by J. A. Hyslop, as *Ludius pyrrhos* (Herbst). Larval exuviae of 3 specimens, labeled 6066, 6067, and 6069, and a much desiccated whole larva, labeled 6075, were found and examined. The notes indicate that specimen No. 6068 was reared, and an adult of *Ludius pyrrhos* (Herbst) bearing this number has been reported by M. C. Lane to be in the collection at the Wireworm Laboratory, Walla Walla, Wash. Mr. Lane confirmed the identification of this adult. Unfortunately, the larval exuvium of No. 6068 was not available, but the evidence strongly suggests that the material that was examined was of this species. The larval material is now in the U. S. National Museum.

LUDIUS PROTRACTUS (LeConte)

Corymbites protractus LECONTE, Proc. Acad. Nat. Sci. Philadelphia, p. 85, 1859.

Ludius protractus (LeConte), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 410, 1932.

Van Dyke (1932, pp. 392, 410) states that this species is widely distributed along the Pacific coast from British Columbia to northern California, and that it is a meadowland species. This suggests that the larva lives in the soil. The specimen examined was found as a pupa on June 19, which indicates a rather early seasonal development.

Additional larval material is necessary before a complete detailed description can be given and before reliable structural characters are known for the separation of *protractus* and *pyrrhos*.

Material used in study.—Only the larval exuvium of a reared specimen was available for examination. W. J. Brown, of Ottawa, confirmed the identification of the reared adult.

1; Towle District, Placer County, Calif.; June 19, 1932; collected as a pupa which emerged immediately; H. H. Keifer. (U.S.N.M.)

THE LUDIUS LIMONIIFORMIS GROUP

FIGURES 11, *h*; 29

KEY TO SPECIES

- With 5 or more "teeth" laterally on dorsum of ninth abdominal segment (*to*, fig. 29, *b*); larva rarely exceeding 20 mm. in length; west of Lake Superior *limoniiformis* (Horn) (?) (p. 151)
- With 4 "teeth" laterally on dorsum of ninth abdominal segment (*to*, fig. 29, *e*); larva might exceed 30 mm. in length; eastern North America....
..... *cylindriformis* (Herbst) (?) (p. 156)

This group is represented in the larval stage by two species that are not positively identified, but which are believed to be *limoniiformis* (Horn) and *cylindriformis* (Herbst).

These larvae are soil inhabiting, apparently preferring relatively moist situations. Both species are minor pests of cultivated plants.

Ludius limoniiformis and *L. cylindriformis* larvae are easily separated and might eventually be placed in different species groups, but they possess many characters in common and are not closely allied to any other of the known *Ludius* larvae. The body is relatively long and narrow, most of the abdominal segments being as long as wide. Eyes are absent and the presternum of prothorax is undivided. Other important characters are found in the urogomphi (fig. 29, *b-e*), the dorsum of the ninth abdominal segment (fig. 29, *b, e*)—especially the sharp marginal "teeth" (*to*) and the lack of a mediodorsal groove—and the nasale (fig. 29, *a*).

The larvae of the *limoniiformis* group are light brown or yellow brown. Caudal notch small, subcircular or subovate, nearly closed posteriorly. Urogomphi bifid; inner prong broad, with 1 or more tubercles on posterior aspect; tip of outer prong sharp, inclined inward or forward. Ninth abdominal segment (fig. 29, *b, e*) with 4 or more prominent, sharp "teeth" (*to*) on lateral aspects of dorsum and with 4 unpaired setae on the central dorsal area, but without a median longitudinal groove. Nasale (fig. 29, *a*) with tridentate tip, lateral denticles small and frequently eroded off. Frontoclypeal area truncate posteriorly. Second joint of antenna bearing 1 "sensory" appendix. Basal joint of labial palpus without setae. Eyes absent. Gula short, narrow. Presternum of prothorax undivided. Episterna of mesothorax and metathorax with several spinelike setae. Abdominal mediotergites with some of prominent setae paired (usually 2 pairs) or in a semipaired arrangement, and in second to fifth segments with transverse branches of impressions reaching to or nearly to the mid-dorsal suture. First 8 abdominal segments with small pleurites,

becoming narrower in more posterior segments; sternum undivided; and spiracles in anterior half of each segment.

LUDIUS LIMONIIFORMIS (Horn) (?)

FIGURES 11, *h*; 29, *a-c*

Corymbites limoniiformis HORN, Trans. Amer. Ent. Soc., vol. 3, p. 320, 1871.
Ludius limoniiformis (Horn), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 420, 1932.

According to Van Dyke (1932, pp. 396, 420) this species "seems to be rather widely spread in the country to the west of the Great Lakes," and apparently extending into Alberta.

The larvae are known from the parklands of Saskatchewan, where they are found most frequently in association with the grassy margins of snowberry (*Symphoricarpos*) and silverberry (*Elaeagnus*) thickets. The species persists for many years after such areas are brought under cultivation. King (1928, p. 705) refers to *L. limoniiformis* as a crop pest of minor importance in Saskatchewan.

This larva resembles the more eastern *cylindriformis* (Herbst) but is smaller, and has more "teeth" on the margins of the dorsum of the ninth abdominal segment (fig. 29, *b*).

Description of "mature" larva.—Length 16.5 mm.; greatest breadth 2.0 mm.; thoracic and abdominal segments subequal in width with prothorax sometimes widest segment. Fully distended larva measured 22 mm. Body only moderately robust; with moderate-sized membranous areas on lateral aspect; most segments of abdomen as long as wide; head and ninth abdominal segment about five-sixths greatest body width. Dorsum light brown to yellowish brown (near "clay color," Ridgway, 1912); head and prothorax distinctly darker; venter slightly paler. Dorsum slightly rugose, more pronounced rugosity on abdomen; with sparse small punctures, more abundant on more posterior segments.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 29, *a*) a well-developed tooth terminating tridentate when uneroded; median denticle large, small lateral denticles frequently eroded giving appearance of unidentate tip. Subnasale (*sn*) consists of many fine, short, sharp, forward-projecting denticles; frequently eroded. Paranasal

lobes produced beyond nasale; each bearing 3 setae, 1 very small and sometimes lacking.

Epicranial plates smooth, or with few small pits. Dorsal sulci shallow; each with 5 setae subequally spaced, most anterior seta long, others small. Ventral sulci bearing row of 5 to 8 setae, usually only 2 or 3 conspicuous. Two large, unpaired, lateroepicranial setae. Eye spot absent; normal eye region bordered by 2 unpaired setae. Postgenal areas expanded mesally, almost meeting; glabrous.

Gula short, narrow; goblet-shaped; constricted posteriorly by converging postoccipital sutures; glabrous.

Antenna with first joint weakly clavate; almost two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, about two-thirds as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae or pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-half as long as second segment and one-quarter as wide; 4 setae and 2 or 3 "sensory" pegs on apex.

Mandibles of moderate length, robust; about two-thirds as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and moderately convex dorsally.

Ventral mouthparts about four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-lateroventral aspect. Galea with basal joint slightly longer and one-half wider than terminal segment, without setae or pores; terminal joint curved, lateral surface longer than inner surface, 2 or 3 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint slightly longer than wide; distally on mesoventral aspect with group of about 6 small pores and 2 setae. Second segment as wide as basal joint and longer; without setae; 3 or 4 pores. Third segment about as wide as long; about one-half length of second joint; 2 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth joint longer than wide; nearly as long as third joint; sometimes 1 minute seta on medial aspect; 1 pore on lateral surface. Postmentum with 1 long seta near each corner. First prementum

with 1 large seta just caudad to base of each palpus. Labial palpus with basal joint cylindrical, about one-half length of first prementum, about as long as wide, without setae, 3 or 4 pores; terminal joint shorter than basal joint and about one-half as wide, without setae, 1 or 2 pores.

Prothorax about equal to combined length of mesothorax and metathorax; wider posteriorly; about as long as wide. Tergites minutely punctulate; anteriorly with 5 setae (on each side of median dorsal suture) in transverse row, arranged as 2 pairs with 1 unpaired seta between, the unpaired hair often found near the more lateral pair giving appearance of group of 3 setae; posteriorly with 4 setae in transverse row, arranged as 1 pair with 2 unpaired setae farther laterad; glabrous elsewhere. Episternum with 1 large and usually 2 smaller setae. Epimeron bearing 1 small seta. Presternal area consisting of 1 large triangular sclerite, posteriorly acute, striate on anterolateral aspects, 1 prominent seta near each lateral margin, and 2 short diagonal rows each of 4 minute setae anteriorly near middle. Eusternum small, membranous, with small narrow median sclerite. Sternellum and poststernellum indefinite, small and largely membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression variable in length, commonly extending about one-fourth distance from longitudinal branch to middorsal suture; longitudinal branch of impression very short or absent. Anterior part of each mediotergite sometimes with several minute setae issuing from punctures; 2 or 3 small setae arranged as follows: 1 just behind transverse branch of impression, 1 just laterad to impression, and sometimes 1 near medial end of impression or slightly farther mediad. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, the 2 most medial paired; sometimes 1 minute seta just caudad to the most lateral of the large hairs. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 10 spinelike setae, usually 6 to 8. Mesothoracic spiracle subequal in size to spiracles in abdomen.

Legs subequal in length. Coxa of prothoracic leg usually with from 25 to 32 spinelike setae on anterior surface, mesothoracic and metathoracic legs with from 20 to 27 such setae; 6 to 8 stout setae and a few finer hairs on posterior aspect. Trochanter with 5 to 8 spinelike setae on medioanterior surface; 5 to 7 such setae and 1 fine seta on posterior surface; 2 long setae on medial aspect. Femur

usually with 5 to 7 spinelike setae on medioanterior surface; 2 or 3 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 minute setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 2 or 3 spinelike setae on medioanterior surface; 2 or 3 spinelike setae on posterior face. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; seventh and eighth segments very slightly narrower. Mediotergites somewhat rugose and with small shallow punctures, rugosity and punctation becoming stronger from first to eighth segments; transverse branches of impressions sinuate, reaching to or nearly to middorsal suture on second to fifth segments, sometimes nearly as long on sixth segment, shorter on other segments especially first and eighth; longitudinal branch of impression extending approximately one-half distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite usually with 4 setae, 2 (rarely 3) lying within transverse branch of impression, 1 toward middle of sclerite, equidistant from branches of impression, and 1 laterad to impression. Posterior part of each mediotergite with 5 large setae arranged as 2 pairs (sometimes only semipaired) and 1 unpaired seta farther laterad; sometimes 1 minute seta near unpaired large hair; sometimes, especially on more posterior segments, up to 5 additional small setae, usually slightly posterior to row of larger setae. Laterotergite I extending length of segment; with 1 large seta. Spiracles subequal; in extreme posterior end of spiracular sclerite, which is small, subovate, about twice length of spiracle and situated in anterior half of each segment. Pleurite small, becoming narrower in more posterior segments; with 1 prominent seta and sometimes 1 or 2 minute hairs. Sternum of 1 piece, subquadrate; without definite impressions or sutures, but with a few small shallow pits; bearing 1 prominent seta near each corner and usually a few minute setae along lateral margins.

Ninth abdominal segment (fig. 29, *b*), exclusive of urogomphi, slightly shorter than eighth abdominal segment and almost as wide; as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about three-fifths to two-thirds greatest width of segment. Dorsum flat to slightly convex, sloping downward from front to back. Dorsal plate (*dpla*) roughened by irregular lines, wrinkles, and a few scattered pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedial pair (*pim*) which converge posteriorly but do not meet;

2 prominent fine setae anteriorly and 2 smaller setae farther caudad; lateral margins slightly raised and carinate, typically with 5 prominent, sharp, setiferous "teeth" (*to*), sometimes with smaller "teeth" between larger ones, as many as 8 or 9 "teeth" on each side in some specimens; transverse impression (*trin*) continues across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 20 to 35 setae on each side, many issuing from small sclerotized tubercles; anteriorly on lateral aspect with a few pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fourth total length of segment (exclusive of urogomphi). Pleural area large, transversely striate with small ovate sclerite near anterior ends. Sternum of 2 sclerites, separated anteriorly by faint median suture and posteriorly by tenth abdominal segment; each sclerite with from 5 to 10 setae, mostly in irregular row adjacent to tenth abdominal segment.

Urogomphi (*ur*, fig. 29, *b*; fig. 29, *c*) separate, bifid; projecting dorsocaudad; prongs subequal in length, but differing in shape. Inner prong (*ipr*) robust, subquadrate (rarely subtriangular), projecting caudomedial; anteromedial margin strongly sclerotized, dark; with 1 or 2 setiferous tubercles (*tub*) on caudolateral aspect, another seta just ventrad to tubercles and usually a few minute setae scattered over caudal aspect. Outer prong (*opr*) less robust, corniform, projecting caudad or dorsocaudad, sometimes slightly laterad; terminating in sharp horny point usually curving slightly forward or inward; with a prominent setiferous tubercle situated caudolaterally near base of prong; 1 prominent seta on inner aspect, about halfway up prong, 1 smaller seta on posteromedial surface and 1 minute seta medially near base of prong. Undivided part of urogomphus short, broad; usually with 1 very short, fine seta near midventral aspect. Caudal notch (*cn*) small, subcircular, almost closed by incurving inner prongs.

Tenth abdominal segment with whorl of 10 fine setae, sometimes a few additional minute setae; anal aperture linear and median.

Material used in study.—Twenty-one larvae, all from Saskatoon, Saskatchewan, were examined. This species has not been reared, and identification is based upon field association of larvae and adults. However, misidentification is unlikely because nearly all other elaterid larval types occurring in fields at Saskatoon have been identified through rearing. The material examined is deposited in the Canadian national collection.

LUDIUS CYLINDRIFORMIS (Herbst) (?)

FIGURE 29, *d, e*

Elater cylindriformis HERBST, *Natursyst. Ins. Käfer*, vol. 10, p. 93, 1806.

Corymbites cylindriformis (Herbst), GERMAR, *Zeitschr. für die Ent.*, vol. 4, p. 64, 1843.

Ludius cylindriformis (Herbst), VAN DYKE, *Proc. California Acad. Sci.*, vol. 20, p. 399, 1932.

This species is known from the eastern provinces of Canada and from the northeastern United States and at least as far west as Indiana, where Blatchley (1910, p. 765) reports its occurrence as "frequent."

The larvae have been taken from cornfields and gardens, and Hyslop (1915a, p. 9) reports the adults as being abundant in alfalfa and wheat fields. Hawkins (1936, pp. 55-56) implies that the species is a minor crop pest in Maine, but a predaceous tendency is suggested from the observations of Devereux (1878, p. 143), who found a larva crushing the elytron of a living *Harpalus pennsylvanicus*. A hibernating larva was found on December 15 at a depth of 1 foot in a cornfield.¹²

No adequate description of the larva has been published, but Hawkins (1936, p. 59, fig. A) figured the ninth abdominal segment. Distinction from the larva of *limoniiformis* (Horn) is made primarily through greater size, characters of the ninth abdominal segment (fig. 29, *e*), and the mandibles.

The largest larva examined was not fully distended, but measured 30 mm. in length and 2.6 mm. in breadth. The mandibles are distinguished as follows: Beginning at the distal end of the antennal fossa, a shallow groove extends one-third to one-half the distance toward the tip of the mandible. The ninth abdominal segment (fig. 29, *e*) bears only 4 sharp "teeth" on each lateral margin of the dorsum; distance between pleural area and caudal notch approximates one-fifth to one-sixth total length of segment, exclusive of urogomphi; lateral and ventral aspects of tergite with fewer setae than *limoniiformis*, usually less than 20 setae on each side. The larvae examined possessed a few transverse rugae or pits on the abdominal mediotergites, especially within the angle of the impressions.

Material used in study.—Five larvae were examined, four from Springhill, New Brunswick, and one from Riverton, N. J. The species has not been reared, but the material examined appears to be similar to the larva described by Hawkins (1936) as *L. cylindri-*

¹² This observation was made at Riverton, N. J., by C. A. Thomas, of Kennett Square, Pa., and the larva was identified by the writer.

formis. Specimens examined are deposited in the Canadian national collection and the Pennsylvania Agricultural Experiment Station collection.

Genus **LIMONIUS** Eschscholtz

FIGURES 9, *g*; 10, *c*; 11, *a, d, g*; 30-32

In the present study, the name *Limonius* Eschscholtz is used in the broad sense, including all species that have been placed in *Pheletes* Kiesenwetter and *Nothodes* LeConte. The larval morphology suggests this procedure to be best for the present at least. Hyslop (1921) has shown *Pheletes* to be isogenotypic with *Limonius*, and Van Dyke (1932, p. 333) suppresses the name *Nothodes*, placing its lone species, *dubitanus* LeConte, in *Limonius*.

Accurate specific identification of the larvae of this genus is made doubly difficult because of the apparent unsettled status of the taxonomy of the adults. A thorough revision of the genus would greatly assist in naming the larvae.

Larvae of 14 species of *Limonius* have been studied, 12 from North America and 2 from Europe.

Dr. Van Dyke (1932, pp. 333, 360) states that with one exception the genus is holarctic in distribution and shows a preference for valleys and more open places. The great majority of the larvae studied are soil inhabiting and in North America are important pests in fields and gardens. Only one species, unidentified, is known to occur in decaying wood, but a few prefer moist forest litter.

On the basis of rather scanty information it appears that pupation occurs most commonly in July or early August. The newly developed adults pass the winter in their pupal chambers.

Limonius is part of that large, complex group whose larvae possess an undivided prosternum (*prst*, fig. 31, *c*), have impressions on the mediotergites of mesothorax and metathorax, and with one exception, *L. pilosus* (Leske), have the nasale tridentate at the tip. On the basis of larval characters the closest allies appear to be *Elathous bicolor* (LeConte), *Ludius resplendens* (Eschscholtz), and species of the *Ludius limoniiformis* group.

Generic separation is greatly facilitated if *Limonius* larvae are considered in two artificial groups: *Group I*, caudal notch small; outer urogomphal prongs reduced to the size of small tubercles (figs. 30, *d, f*; 31, *d, e*). *Group II*, caudal notch small; outer urogomphal prongs at least moderately well developed (figs. 30, *h*; 31, *f*; 32, *d, e*), sometimes as long as inner prongs; and ninth abdominal segment (figs. 30, *h*; 32, *d*) without a mediodorsal groove and with well-rounded "teeth" (*to*) on lateral aspects of dorsum. *Group I* is

distinct from all other known larvae in this complex of related genera. *Group II* is separated from *Elathous bicolor* and *Ludius resplendens* through the absence of the mediodorsal groove on the ninth abdominal segment, and from larvae of the *Ludius limoniiformis* group by the blunt "teeth" on the same segment.

Limonius larvae may be characterized as follows: Dorsum pale yellow (or orange-yellow) to yellow-brown, with minute (inconspicuous) to moderate-sized punctures, but lacking prominent transverse rugae. Caudal notch small. Urogomphi bifid, prongs subequal or outer prongs shorter than inner prongs. Ninth abdominal segment usually without a mediodorsal groove, and without "teeth" or with well-rounded "teeth" on lateral margins of dorsum. Nasale variable, but usually tridentate at tip. Frontoclypeal area truncate or broadly rounded posteriorly. Eyes present or absent, with 2 to 4 setae around eye region. Usually 2 unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandibles variable (figs. 30, *c, e*; 32, *b*). Presternum of prothorax (fig. 31, *c*) undivided. Mesothorax and metathorax with impressions on mediotergites. Abdominal mediotergites with impressions of varying length; and usually with 5 to 7 prominent setae in posterior transverse row, definitely arranged as 2 or 3 pairs in nearly all species.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF LIMONIUS

1. Outer prongs of urogomphi reduced to the size of small tubercles (*opr*, figs. 30, *d, f*; 31, *d, e*)..... 2
 - Outer prongs of urogomphi pronglike (*opr*, figs. 30, *h*; 31, *f*; 32, *d, e*).. 5
2. Ninth abdominal segment with 2 conspicuous conical protuberances (*pro*, fig. 31, *e, g*)..... **pectoralis** LeConte (p. 161)
 - Ninth abdominal segment without such protuberances..... 3
3. Mandible (fig. 30, *c*) with prominent toothlike expansions anterior to retinaculum; nasale (*n*, fig. 30, *a, b*) short, with 3 subequal teeth....
 -the **aeneoniger** group (p. 159)
 - Mandible without toothlike expansions anterior to retinaculum..... 4
4. Eyes absent; ninth abdominal segment without a definite mediodorsal groove; each paranasal lobe with a cluster of 12 or more "sensory" pores (*pulp*, fig. 32, *a*)..... **aeger** LeConte (p. 163)
 - Eyes present; ninth abdominal segment with a mediodorsal groove; paranasal lobes without definite cluster of pores.....
 -unidentified, possibly **confusus** LeConte (p. 162)
5. Nasale (*n*, fig. 30, *g*) of 1 pointed tooth; mandible (fig. 30, *e*) with very large retinaculum and expanded medioventral cutting edge;
 - European **pilosus** (Leske) (?) (p. 160)
 - Nasale (*n*, figs. 31, *b*; 32, *a*) with tip tridentate; mandible (fig. 32, *b*) without above characteristics; North American..the **canus** group (p. 164)

THE LIMONIUS AENEONIGER GROUP

FIGURES 9, *g*; 11, *a*; 30, *a-d, f*

Only two species are included in this group, one from Europe, the other from western North America. The larva of the genotype, *Limonius aeneoniger* (DeGeer) (= *Pheletes Bructeri* Panzer), is recorded by Beling (1884, p. 205) from earth in dry, sunny places in European forests, preferably under moss. H. P. Lanchester, of Walla Walla, Wash., collected larvae of the Pacific coast species, *L. consimilis* Walker, "in moss on boulders in shade."

This strongly characterized group is distinguished as follows: Mandible (fig. 30, *c*, probably considerably eroded) with prominent toothlike expansions anterad to retinaculum; nasale (*n*, fig. 30, *a, b*) short, with 3 subequal teeth; subnasale (*sn*) with 1 prominent obtuse tooth; and abdominal mediotergites with transverse branches of impressions short, extending less than one-half distance from longitudinal branches to middorsal suture.

Preserved larvae are yellow to yellow-brown in color, with head and prothorax darker, but living specimens appear to differ since Beling (1884, p. 205) reports "larva intense yellow-red" and Lanchester (1941, p. 368) records *consimilis* as "orange-yellow" when collected. Both are relatively small species, *aeneoniger* attaining 9 mm. in length, and the largest *consimilis* examined measuring 13 mm.

Urogomphi (*ur*, fig. 30, *f*; fig. 30, *d*) with outer prongs (*opr*) very small. Ninth abdominal segment (fig. 30, *f*) without mediiodorsal groove (sometimes with a shallow, central, subcircular depression); without setae on central dorsal area; "teeth" (*to*) very small, practically wanting, on lateral aspects of dorsum; and distance between caudal notch and pleural area about one-fifth length of segment, exclusive of urogomphi. Frontoclypeal area (fig. 30, *a*) truncate or broadly rounded posteriorly. Paranasal lobes (*pnl*) without definite pore cluster. Eyes present. Two prominent unpaired lateroepicranial setae on each gena. Without setae on ventral aspect of basal segment of labial palpus. Mesothorax and metathorax without spinelike setae on episterna (usually 1 fine seta on each episternum). Abdominal mediotergites finely punctured and each with 2 or 3 pairs of setae in posterior transverse row.

Material used in study.—*L. aeneoniger* (DeGeer): Only 2 specimens were available for examination, 1 from Norway, the other from Denmark. As far as is known, neither of these was associated

with reared material. Specimens deposited in the U. S. National Museum.

L. consimilis Walker: Nineteen specimens collected at Asotin, Wash., were examined. These were received through the courtesy of M. C. Lane and H. P. Lanchester, of Walla Walla, Wash. Mr. Lanchester reared larvae from the same collection. The reared adults were identified by M. C. Lane and placed in the collection of the Wireworm Laboratory at Walla Walla. Larvae examined are deposited in the Canadian national collection.

LIMONIUS PILOSUS (Leske) (?)

FIGURE 30, *e, g, h*

The larva of this European species has been described by Beling (1883, p. 302; 1884, p. 205), Rey (1887), and Henriksen (1911, pp. 255-256) under the name of *nigripes* Gyllenhal. In the present study examination has been confined to one larva from Amager Falded, Denmark, that is believed to be identical with that described by these authors. This specimen is deposited in the U. S. National Museum.

According to Beling and Henriksen, the larva inhabits the soil, chiefly in meadowland.

This larva differs from all other *Limonius* larvae known to the writer, as follows: Nasale (*n*, fig. 30, *g*) unidentate, sharply pointed when uneroded; subnasale (*sn*) consisting of a transverse ridge bearing about 8 subequal forward-projecting denticles; and mandible (fig. 30, *e*) with greatly enlarged retinaculum (*ret*) and expanded ventral cutting edge. Rey (1887) states that the larva of *Limonius cylindricus* Paykull is very similar.

Length 14.5 mm., as recorded by Henriksen and Beling. Outer prongs of urogomphi (*opr*, fig. 30, *h*) shorter than inner prongs (*ipr*), but definitely pronglike. Dorsum of ninth abdominal segment (fig. 30, *h*) apparently without a median sulcus, without setae on central area, and with small, blunt "teeth" (*to*) on lateral aspects. Frontoclypeal area truncate posteriorly. Eyes present. Two unpaired lateroepicranial setae on each gena. Five or six spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with small punctures, prominent setae arranged in definite pairs, and with transverse branches of impressions extending about four-fifths of distance from longitudinal branches to middorsal suture.

LIMONIUS PECTORALIS LeConte

FIGURE 31, *a, e, g*

This northern species is known from Alaska and from coast to coast in Canada. Larvae have been reared from Cleeves, Saskatchewan.

This species is of considerable economic importance in the parklands of northern Saskatchewan and the Peace River Block of Alberta and British Columbia. As reported by King (1928, p. 704), *pectoralis* appears to be definitely associated with deep, rich, loam soils, and somewhat low-lying situations, and under native conditions prefers the grassy margins of snowberry (*Symphoricarpos*) thickets.

After a lengthy period of drought larvae were found on June 30 as deep as 19 inches in an old bromegrass field. However, it would appear that pupation occurs much nearer the soil surface, since overwintering adults have been taken at depths between 2 and 4 inches. Rearing records indicate that pupation occurs in late summer or early autumn, but the exact time is not known.

The larva of *pectoralis* differs from other known elaterids in having 2 prominent conical protuberances on the dorsum of the ninth abdominal segment (*pro*, fig. 31, *e, g*). The nasale (fig. 31, *a*) is also characteristic, the median denticle being smaller than the lateral denticles.

The largest larvae examined measured 14 mm. Outer prongs of urogomphi (*opr*, fig. 31, *e, g*) are reduced to mere, pointed tubercles. Ninth abdominal segment without a mediodorsal sulcus, without "teeth" (rarely 1 or 2 minute swellings) on lateral aspects of dorsum, and distance between caudal notch and pleural area approximates one-eighth to one-sixth length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Eyes absent. Two unpaired lateroepicranial setae on each gena. Mandible of common lepturoidine type, with well-developed retinaculum. One small seta on ventral surface of basal segment of labial palpus. Mesothorax and metathorax with impressions indistinct on mediotergites, and with 4 to 6 spinelike setae on each episternum. Abdominal mediotergites with impressions reaching the middorsal suture on second to eighth segments, with fine, scattered punctures, and with 3 pairs of setae in posterior transverse row.

Material used in study.—Fifteen examples were examined, including the larval exuviae of two reared specimens. All the material was from the parklands of Saskatchewan except 7 larvae from Fairbanks, Alaska. The following notes pertain to the reared material:

2; Cleeves, Saskatchewan; (no date); both reared to adults by Nov. 15, 1926; K. M. King. (C. N. C.)

LIMONIUS CONFUSUS LeConte (?)

A few larvae of this species have been collected at Urbana and Danville, Ill., and at Arnprior, Ontario. This is a typical forest species, the larvae occurring in decaying wood and in moist, well-decayed leaf litter.

The identity of these larvae is unknown, but it is most likely to be either *L. confusus* LeConte or a closely allied species. W. J. Brown, of Ottawa, informs the writer that *confusus* LeConte is found in the woods and is the most common *Limonius* at Arnprior. Blatchley (1910, p. 758) reports that the adults of *confusus* are found beneath the bark of oak and other trees, but that the species is scarce in Indiana.

It is possible that there is some error in the reference by J. J. Davis (1911, p. 251) to *L. confusus* larvae damaging truck crops in Illinois. I have examined the larval exuvium of a specimen collected by Mr. Davis, the reared adult of which was identified by J. A. Hyslop as *Limonius confusus* LeConte. This larval skin bears structures of great similarity to those of the larva of *L. dubitans* LeConte, and on this basis Mr. Davis' species would be placed in the *canus* group, which includes *L. canus* and *L. dubitans* and their close allies. However, Mr. Brown, of Ottawa, informs me that, on the basis of adult characters, *confusus* and *dubitans* belong in distinct species groups. Blatchley (1910, p. 762) states that *L. dubitans* "resembles so closely *Limonius griseus* that it can with difficulty be separated." Both of these species occur commonly in Indiana and undoubtedly in Illinois. Davis' larva is more likely to be one of these soil-inhabiting species than the woodland *confusus*. It is unfortunate that the adults reared by Mr. Davis are either lost or misplaced and Mr. Hyslop's original identification cannot be checked.

The larva which is provisionally named *confusus* LeConte in the present study belongs to that group of *Limonius* that have very small outer urogomphal prongs. Its other chief characteristics are the presence of a mediodorsal groove on the ninth abdominal segment; prominent setae unpaired on abdominal mediotergites; eyes present; and paranasal lobes without a definite cluster of pores.

The largest larva examined measured 18 mm. in length. The ninth abdominal segment bears 2 very small (inconspicuous) setae anteriorly on dorsal plate; small, blunt "teeth" on lateral aspect of dorsum; and distance between caudal notch and pleural area approximates one-fifth total length of segment, exclusive of urogomphi. Nasale with tip

tridentate. Frontoclypeal area truncate posteriorly. Three latero-epicranial setae on each gena, arranged as a dorsal pair and 1 unpaired hair farther ventrad. Mandibles robust. Without setae on ventral surface of basal segment of labial palpus. With 1 to 4 setae (rarely spinelike) on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions not extending to middorsal suture; and bearing sparse, small punctures.

Specimens examined are deposited in the Canadian national collection.

LIMONIUS AEGER LeConte

FIGURES 11, *d*; 31, *d*

According to Van Dyke (1932, p. 339) this species occurs from Nova Scotia and the New England States west to British Columbia and south through the Rocky Mountains to New Mexico and from the Cascade Mountains to Mount Hood, Oreg. Larvae have been reared from Saskatoon, Saskatchewan.

Under Saskatchewan conditions this species is found in forest litter and in the superficial layers of soil under the litter. The larvae have been collected in greatest abundance under mixed shrubs and poplar along the banks of the Saskatchewan River. In the muck soils of southern Quebec and Ontario, larvae believed to be of this species are injurious to vegetables. Rearing records indicate that pupation normally occurs in soil or litter from late July to early August.

The larva of *aeger* belongs to that group of *Limonium* that have very small outer urogomphal prongs (*opr*, fig. 31, *d*). It shows superficial resemblance to the larva provisionally regarded as *confusus* LeConte, but differs as follows: Eyes absent; ninth abdominal segment without mediadorsal groove (sometimes with a shallow subcircular depression bearing short, paired paramedian grooves), and with a sinuate "impression" laterally near base of segment; prominent setae paired on mediotergites of abdominal segments; each paranasal lobe bearing a cluster of 12 or more "sensory" pores; and usually 4 to 7 spinelike setae on each episternum of mesothorax and metathorax.

The largest larvae attain 12 mm. in length. Ninth abdominal segment without setae on central dorsal area, small and much-rounded "teeth" on lateral aspect of dorsum, and distance between caudal notch and pleural area approximating one-fifth to one-fourth length of segment, exclusive of urogomphi. Nasale with tip tridentate. Subnasale of many fine teeth. Frontoclypeal area truncate posteriorly. Two prominent unpaired lateroepicranial setae on each gena. Abdominal

mediotergites with fine scattered punctures, and with transverse branches of impressions reaching about four-fifths of the distance from the longitudinal branches to the middorsal suture.

Material used in study.—Thirteen examples were examined, including the larval exuviae of three reared specimens. All material was from Saskatoon, Saskatchewan, and is now in the Canadian national collection. The reared adults were identified by W. J. Brown, of Ottawa. Notes follow on the reared material.

- 6; Saskatoon, Saskatchewan; July 13, 1935; 1 reared to adult July 30, 1935; R. Glen.
7; Saskatoon, Saskatchewan; July 21, 1937; 2 reared to adults Aug. 3, and Aug. 20; R. Glen and H. McDonald.

THE LIMONIUS CANUS GROUP

FIGURES 10, *e*; 11, *g*; 31, *b, c, f*; 32

PROVISIONAL KEY TO SPECIES¹³

1. From eastern North America, including the Great Lakes region..... 2
From western North America, including the Great Plains region..... 3
2. Abdominal mediotergites (fig. 32, *c*) with impressions extending to or nearly to the middorsal suture on second to fifth segments; New York to Indiana.....*dubitans* LeConte
Abdominal mediotergites with shorter impressions; eastern Canada and northeastern United States..... $\left\{ \begin{array}{l} \text{ectypus (Say) (?) (=} \\ \text{agonus Say)} \\ \text{anceps LeConte (?)} \end{array} \right.$
3. Urogomphi with outer prongs hook-shaped (*opr*, fig. 31, *f*; eastern Washington, and Idaho to northern California..*subauratus* LeConte (?)
Outer urogomphal prongs not hook-shaped (fig. 32, *e, f*)..... 4
4. Abdominal mediotergites with impressions (as in fig. 32, *c*) extending to or nearly to the middorsal suture on second to fifth segments..... 5
Abdominal mediotergites with shorter impressions; British Columbia and the Pacific States.....*canus* LeConte
5. From Manitoba, Saskatchewan, and Alberta.....
.....*Limonius* sp., near *ectypus* (Say)
From the Pacific area..... $\left\{ \begin{array}{l} \text{californicus (Mannerheim)} \\ \text{occidentalis Candeze (?)} \end{array} \right.$

The larvae of eight North American species have been included in this group. Of these, *L. canus* LeConte and *L. dubitans* LeConte

¹³ Since this study was completed, H. P. Lanchester has published a paper containing a key to the larvae of six species of this group: "Larval Determination of Six Economic Species of *Limonius*," *Ann. Ent. Soc. Amer.*, vol. 39, pp. 619-626, 1946.

are believed to be reliably named. The larvae regarded as *L. ectypus* (Say) and *L. anceps* LeConte have been identified provisionally on the basis of geographic distribution and field association with adults of these species. Considerable uncertainty surrounds the identification of the larvae here designated as *subauratus* LeConte and *occidentalis* Candeze. The following changes might be in order: *L. subauratus* changed to *infuscatus* Motschulsky and *occidentalis* changed to *subauratus* LeConte. However, the names used in the present discussion are those that were found on the labels accompanying the specimens examined.

The *canus* group includes some of the most important pest species in America. All are soil inhabiting and all have been reported as injuring cultivated plants. With reference to the Pacific coast species, Lane (1935, p. 530) reports that the larvae inhabit moist soils, such as stream margins, low-lying lands, and irrigated fields, and thrive especially in alkaline areas. Similar habits have been observed for the larvae of "*Limonium* sp. near *ectypus* (Say)" occurring in the Prairie Provinces. The eastern species also are known to inhabit moist areas, but frequently are taken from sandy soils that are relatively well drained.

Very little has been published on the life history of these species, but it appears that pupation normally occurs in late July or early August, with the adults overwintering in their pupal chambers.

The morphology of the larva of *L. canus* LeConte has been studied in detail by Lanchester (1939).

Larvae of the *canus* group differ from other known *Limonium* larvae in that the prongs of the urogomphi are subequal in length. This group is further characterized as follows: Relatively large larvae, sometimes attaining 25 mm. in length when mature; each paranasal lobe with a cluster of 12 or more "sensory" pores (*pnlp*, fig. 32, *a*); eyes absent; with 1 small seta on ventral aspect of basal segment of labial palpus; maxillary palpus with second segment longest; 6 to 12 spinelike setae on each episternum of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae arranged in pairs (fig. 32, *c*); dorsal plate of ninth abdominal segment (figs. 11, *g*; 32, *d, f*) with 2 or 4 unpaired setae, without medio-dorsal groove (sometimes with shallow subcircular depression), and with well-rounded "teeth" (*to*) or tubercles on lateral margins; in ninth abdominal segment the distance between caudal notch and pleural area approximates one-sixth total length of segment, exclusive of urogomphi.

Material used in study of the group.—*L. anceps* LeConte: Examination was restricted to 10 larvae collected at Maxfield, Maine. These were provisionally identified by Dr. A. G. Böving, Washington, D. C., as *Limonius anceps* LeConte. (U.S.N.M.)

L. californicus (Mannerheim): Only four larvae were examined. These were reared from eggs secured from adults collected at Walla Walla, Wash., by M. C. Lane, and identified by him. (U.S.N.M.) These larvae were found to be identical to the larvae of *L. canus* LeConte, an error in labeling being the most plausible explanation. Consequently, the key characteristics of *L. californicus* larvae were taken from Lanchester (see footnote, p. 164).

L. canus LeConte: Examination was restricted to four larvae reared from eggs secured from adults collected at Walla Walla, Wash., by M. C. Lane and identified by him. (U.S.N.M.)

L. dubitans LeConte: Six larvae were studied. These were collected from Cornwells, Bucks County, Pa., by C. A. Thomas. Mr. Thomas has reared this larval type and he identified the larval material used as *L. agonus* Say. In a personal communication, Mr. Thomas informed the writer that the species previously identified as *L. agonus* Say is now regarded as being *L. dubitans* LeConte. (U.S.N.M.)

L. ectypus (Say) (?): Ten larvae collected at Chatham, Ontario, were examined. These specimens were taken from cultivated fields where adults of this species were very abundant, but identification was not confirmed by rearing. (C.N.C.)

Limonius sp., near *ectypus* (Say): Twelve examples, including the larval exuvium of one reared specimen, were studied. These specimens were collected from Souris, Manitoba (9), Taber, Alberta (2), and Radisson, Saskatchewan (1). W. J. Brown identified the reared adult. Material associated through rearing is listed below.

6; Souris, Manitoba; June 8, 1938; 1 reared to adult Aug. 16, 1938; H. W. Moore. (C.N.C.)

L. occidentalis Candeze (?): Three larvae were examined. These were in the same vial as five adults, all from Toppenish, Wash. As far as is known the identification was made on the basis of field association of larvae and adults. (U.S.N.M.)

L. subauratus LeConte: Four larvae from Spokane, Wash., were studied. These were taken from the Hagerstown, Md., collection and were labeled, "Web. No. 4675." Ledger records stated that two larvae bearing this number had been reared and their adults identified by J. A. Hyslop as *Pheletes subauratus* LeConte. However, neither the larval exuviae nor the reared adults could be found. (U.S.N.M.)

Genus **ELATHOUS** Reitter**ELATHOUS BICOLOR** (LeConte)FIGURES II, *c*; 33, *a*, *b*

Elathous bicolor (LeConte) is the only species of this genus known in the larval stage. The larvae were collected from decaying wood at Baldwin Hill, Douglas County, Kans., on January 3. One specimen pupated on May 15 and the adult emerged June 4.

This species is undoubtedly closely related to *Athous* and *Lep-turooides*, from which it differs by the combined characters of a small caudal notch and the outer urogomphal prongs being not longer than the inner prongs. It bears resemblance to the larva of *Ludius resplendens* (Eschscholtz), differing by having the outer urogomphal prongs sharp and inclining forward, and by the impressions on the abdominal mediotergites failing to reach the middorsal line. Distinction from *Limonius* larvae is obtained through the combination of prominent outer urogomphal prongs and the presence of a dorsal median groove on the ninth abdominal segment.

The principal characters of the larva of *E. bicolor* may be summarized as follows: Length 14 mm., not fully distended and probably not mature. Dorsum yellow brown. Caudal notch small. Urogomphi (*ur*, fig. 33, *b*; fig. 33, *a*) bifid; prongs subequal in length or outer prongs slightly shorter than inner prongs; outer prong (*opr*) corniform, projecting dorsad with sharp tip inclined forward. Ninth abdominal segment (fig. 33, *b*) with median dorsal groove (*mg*), without setae on central dorsal area, with 3 well-rounded "teeth" on each side of dorsum, and with distance between pleural area and caudal notch about one-fifth total length of segment, exclusive of urogomphi. Nasale with tridentate tip. Eyes present; surrounded by 3 or 4 unpaired setae. Two prominent lateroepicranial setae on each gena, the more dorsal seta paired with a very minute seta. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with well-developed retinaculum. Presternum of prothorax undivided. Mesothorax and metathorax with definite impressions on mediotergites and 3 or 4 spinelike setae on each episternum. Abdominal mediotergites with transverse branches of impressions reaching about three-fourths of distance from longitudinal branches to mid-dorsal suture, and bearing small to moderate-sized shallow pits, but lacking transverse rugae.

Material used in study.—Two examples were examined, one being the exuvium of a reared specimen, the adult of which was identified

by W. J. Brown, of Ottawa. Both specimens were collected at the same time and in the same woods, but from separate decayed logs.

2; Baldwin Hill, Douglas County, Kans.; Jan. 3, 1933; 1 reared to an adult June 4, 1933; C. H. Hoffman. (C.N.C.)

Genus *LEPTUROIDES* Herbst

FIGURES 12, *b*; 33, *c-e*

In following Hyslop (1921), the generic name *Lepturoides* Herbst is used in preference to *Campylus* Fischer and *Denticollis* Piller and Mitterspacher, which are still commonly used by European workers.

Larvae of this genus are known for the European genotype, *Lepturoides linearis* (Linnaeus), and for the North American *denticornis* (Kirby), and a closely allied but unidentified larva from Alaska, which possibly is *fulvus* (Motschulsky). These larvae are very similar and further study and more material are required to secure reliable separating structural characters.

All known *Lepturoides* larvae inhabit the forest, usually occurring under the bark of decaying wood, especially in stumps and logs of deciduous trees. They are believed to be predaceous. Henriksen (1911, p. 269) states that *L. linearis* pupates in May and June, the newly formed adults emerging at once from their pupal chambers. In Pennsylvania, Knull (1934, p. 208) found a pupa of *Lepturoides productus* (Randall) on April 24, from which the adult emerged on May 4; and the author collected larvae of *L. denticornis* in Minnesota on April 8 from which two adults developed by May 4. From these observations, it would appear that in this genus hibernation is limited to the larval stage, that the overwintering larvae normally pupate with the first warm weather, and, in contrast to most Lep-turoidini, the newly developed adults immediately leave their pupal cells for mating and egg laying.

On the basis of larval characters, *Lepturoides* is closely related to *Athous*. It is readily separated by the following combination of characters: Dorsum dark brown to black-brown; caudal notch small; outer urogomphal prongs (*opr*, fig. 33, *d, e*) very long, curving upward and forward; inner prongs (*ipr*) short and smooth, without posterior tubercles; abdominal mediotergites (fig. 33, *c*) punctulate, but without transverse rugae.

The larvae may exceed 20 mm. in length. Dorsum usually very dark, sometimes with a reddish undertone, darkest on prothorax and head; venter pale yellow or cream-colored. Ninth abdominal segment (fig. 33, *d*) with median dorsal groove (*mg*), without setae on cen-

tral area, with 3 or 4 prominent, sharp "teeth" (*to*) on each lateral margin, and with distance between pleural area and caudal notch about one-fifth total length of segment, exclusive of urogomphi. Nasale tridentate at tip. Subnasale with many fine teeth. Frontoclypeal area truncate posteriorly. Eyes large; bordered by 2 prominent unpaired setae. Two large unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with prominent retinaculum, but without other teeth or toothlike expansions. Without setae ventrally on basal segment of labial palpus. Presternum of prothorax undivided. Mesothorax and metathorax with definite impressions on mediotergites, and up to 7 (usually 3 or 4) spinelike setae on each episternum. Abdominal mediotergites (fig. 33, *c*) with impressions reaching mediodorsal suture on all or most of segments, and with small fine punctures, but lacking transverse rugae.

Henriksen (1911, p. 269, fig. 62) depicts the larva of *L. linearis* with prominent rugae on the abdominal mediotergites. This condition was not found on any of the material examined.

PROVISIONAL KEY TO SPECIES OF LEPTUROIDES

1. From Europe *linearis* (Linnaeus)
 From North America..... 2
2. From eastern and central United States and Canada; impressions usually reaching middorsal suture on *all* abdominal mediotergites (fig. 33, *c*) *denticornis* (Kirby)
 From Alaska; impressions usually not reaching middorsal suture on first and eighth abdominal segments..... *fulvus* (Motschulsky) (?)

Material used in the study of the genus.—*L. linearis* (Linnaeus): Thirteen larvae were examined. These were from Denmark (7), Germany (1), Finland (1), and England (4). None of the specimens was known to be associated with reared material. Labeled larvae were received from the U. S. National Museum and from the British Museum of Natural History. These specimens undoubtedly were of the same species and definitely were congeneric with reared larvae of *Lepturoides denticornis* (Kirby). Therefore, it is believed that the material was properly identified.

L. denticornis (Kirby): Eight examples of this species were studied, including the exuviae of two reared specimens. All specimens were taken together from under the bark of an old fallen elm. W. J. Brown, of Ottawa, identified the reared adults.

8; Carter County, Minn.; Apr. 8, 1933; 2 reared to adults on May 4, 1933; R. Glen. (C.N.C.)

Lepturoides fulvus (Motschulsky) (?): Only one larva was examined. This specimen was from Alaska and the identification was made entirely on the basis of locality. (U.S.N.M.)

Genus **ATHOUS** Eschscholtz¹⁴

FIGURES 12, *a, c*; 34-36

Larvae of 14 species of *Athous* have been studied. These are primarily forest forms, living in the litter and decaying wood, and probably are chiefly predaceous. A few European species are found in woodland meadows and cause injury to plants when such areas are brought under cultivation. Larvae of this genus have not been recorded as crop pests in North America.

In America, *Athous* larvae collected in May and June frequently have pupated within a few days after being brought indoors. These findings suggest that some species of *Athous* normally transform to adults in June or early July. However, with species of the *vittatus* group, pupation is reported to occur in late July and August and the adults overwinter in their pupal chambers. Very little is known about the duration of larval life; for *A. haemorrhoidalis* (Fabricius), Roberts (1922, p. 316) suggests 3 or 4 years; for the common American species, there is evidence that indicates a shorter life cycle.

The undivided prosternum (*prst*, fig. 31, *c*), places *Athous* near *Hemicrepidius*, *Lepturoides*, *Elathous*, *Limonius*, and certain species of *Ludius*. Generic distinction is most readily obtained if the larvae of *Athous* are considered in two artificial groups as follows: *Group I*, caudal notch large (figs. 34, *h*; 35, *c*; 36, *a*); eyes present. *Group II*, caudal notch small (fig. 34, *c, d*); outer prongs of urogomphi much longer than inner prongs; dorsum yellow or yellowish brown. *Group I* resembles the larvae of *Hemicrepidius*, but is distinguished by the presence of eyes. *Group II* differs from *Lepturoides* larvae in color, and from the larvae of *Elathous*, *Limonius*, and allied *Ludius* by the long outer prongs. Larvae with large, deep pits or prominent transverse rugae on the abdominal mediotergites (figs. 34, *e*; 35, *e*; 36, *c*; 37, *b*) are either *Athous* or *Hemicrepidius*, depending upon the presence or absence of eyes. The Asiatic *Pleonomus* has been reported by Ghilarov (1937, p. 635) as inseparable in the larval stage from the European *Athous*, but specimens were not available for examination in the present study.

¹⁴ On the basis of larval characters the European *Athous niger* (Linnaeus) and a larva believed to be *Athous hirtus* (Herbst) are typical *Hemicrepidius* and are discussed under that genus.

Excluding *Athous niger* (Linnaeus) and its allies, all the *Athous* larvae examined had the following characters in common: Pre-sternum of prothorax undivided. Urogomphi bifid, usually with prongs subequal or outer prongs longer than inner prongs. Dorsum of ninth abdominal segment with median sulcus, without setae on central area, and with prominent "teeth" (sometimes sharp) on lateral aspects. Nasale tridentate at tip, denticles subequal. Subnasale of many fine teeth. Eyes present. Two unpaired lateroepicranial setae on each gena. Gula of moderate length, but narrow. One "sensory" appendix on second segment of antenna. Mandible usually with well-developed retinaculum but lacking other teeth or toothlike expansions. Definite impressions on mediotergites of mesothorax and metathorax. Abdominal mediotergites with long impressions, reaching at least three-quarters of the distance to the mediodorsal suture; mediotergite sometimes with coarse deep pits or prominent transverse rugae.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF ATHOUS

1. Caudal notch small (fig. 34, *c, d*)..... 2
 Caudal notch large (figs. 34, *h*; 35, *c*) or moderately large (fig. 36, *a*).. 3
2. Abdominal mediotergites with numerous transverse rugae (fig. 34, *e*);
 North America.....the **rufifrons group** (p. 173)
 Abdominal mediotergites without transverse rugae; Europe.....
 the **vittatus group** (p. 171)
3. Urogomphi with outer prongs much longer than inner prongs (fig. 34,
 h); abdominal mediotergites without coarse punctures or prominent
 rugae; Europe.....**A. mutilatus** Rosenhauer (p. 174)
 Urogomphi with outer prongs not longer than inner prongs (figs. 35,
 c, d; 36, *a*); abdominal mediotergites with coarse, prominent scul-
 pture (figs. 35, *e*; 36, *c*)..... 4
4. Caudal notch only slightly narrowed posteriorly (fig. 35, *c, f*); mandible
 (fig. 35, *a*) with medial expansion (*ex*) in region of penicillus;
 North America.....the **cucullatus group** (p. 175)
 Caudal notch considerably narrowed posteriorly (fig. 36, *a, d*); mandible
 without medial expansion at penicillus; Europe and North America..
 the **undulatus group** (p. 177)

THE ATHOUS VITTATUS GROUP

FIGURE 34, *a-c*

PROVISIONAL KEY TO SPECIES

- Inner prongs of urogomphi (fig. 34, *a, c*) with prominent posterior tubercle;
 outer prongs with small denticle on inner aspect (sometimes absent
 through erosion); fine sharp points on "teeth" (*to*) along lateral mar-
 gins of dorsum of ninth abdominal segment.....
**A. haemorrhoidalis** (Fabricius)

Inner prongs (fig. 34, *b*) strongly convex posteriorly, but without tubercles as described above; without fine sharp points on "teeth" on ninth abdominal segment { *A. vittatus* (Fabricius)
A. subfuscus (Müller)

The species placed in this group are enumerated in the key and include *A. vittatus* (Fabricius), which is regarded by Mequignon (1930, p. 95) as the genotype of *Athous*.

Larvae of all species are reported to occur in decaying wood, but the typical larval habitat appears to be in the soil of grassy areas in and around forests. When such areas have been brought under cultivation, the larvae have been reported as damaging domestic plants. Pupation occurs in late July or during August, the adults hibernating in their pupal chambers.

This group may be identified by the following combination of characters: Dorsum bright yellow to yellow-brown; caudal notch small; urogomphi (fig. 34, *a-c*) with outer prongs much longer than inner prongs; abdominal mediotergites finely punctulate, but without prominent transverse rugae.

Larvae of *haemorrhoidalis* are reported by Henriksen (1911, p. 275) to attain a length of 24 mm.; the other species only 18 mm. All species have ninth abdominal segment with 4 prominent "teeth" on lateral margins of dorsum, and distance between caudal notch and pleural area approximating one-fifth of total length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without small seta ventrally on basal segment of labial palpus. Up to 5 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions reaching to or almost to middorsal suture on second to fifth segments, and with 5 to 8 setae (not definitely paired) in posterior transverse row.

Material used in the study of the group.—*A. vittatus* (Fabricius): Five larvae from Vemmetofte, Sealand (Denmark), were examined. These are not known to be associated with reared material, but were received fully labeled from Dr. Mathias Thomsen, Royal Veterinary and Agricultural College, Copenhagen. The identification is believed to be reliable. (C.N.C.)

A. haemorrhoidalis (Fabricius): Three larvae, from France, England, and Denmark, were studied. These were not identified through rearing, but the larva of this species is well known in Europe and the material used is believed to be reliably named. (B.M. and U.S.N.M.)

A. subfuscus (Müller): Five larvae were examined. These specimens were from Germany (2), Finland (1), and Denmark (2). As

far as is known this material was not associated with reared specimens, but the species has been reared in Europe and the material available was similar to that figured by Henriksen (1911, figs. 72-74) as *A. subfuscus*. (C.N.C. and U.S.N.M.)

THE ATHOUS RUFIFRONS GROUP

FIGURE 34, *d-f*

PROVISIONAL KEY TO SPECIES

1. Abdominal mediotergites (fig. 34, *e*) with coarse, conspicuous, transverse rugae; central and eastern United States and Canada..... 2
 Abdominal mediotergites with shallow, less conspicuous rugae; along the coast and mountains from Alaska to California.....
 **A. pallidipennis** Mannerheim
- 2.¹⁵ Urogomphi (fig. 34, *d*) with inner prongs (*ipr*) somewhat ensiform; usually in decaying wood, rarely in leaf litter...**A. rufifrons** (Randall)
 Urogomphi (fig. 34, *f*) with inner prongs (*ipr*) more subquadrate; known only from damp decaying forest litter...**A. brightwelli** (Kirby)

This group is described from the larvae of three North American species. Larvae of *A. rufifrons* have been collected in New Brunswick, Canada, and in Minnesota, Maryland, and Delaware, but larvae of *A. brightwelli* have been taken only in Pennsylvania although the adults are known as far west as Indiana (Blatchley, 1910, p. 759). Larvae of the western *A. pallidipennis* are known only from Walla Walla, Wash.

These are all forest species and probably are chiefly predaceous. Rearing notes for *rufifrons* show that larvae collected in April have matured to adults in May, suggesting that the normal time of pupation is early summer.

Larvae of this group are characterized by the yellow-brown color, the small caudal notch, urogomphi (fig. 34, *d, f*) with outer prongs much longer than inner prongs, and abdominal mediotergites (fig. 34 *e*) with an abundance of transverse rugae.

Mature larvae may exceed 20 mm. in length. Ninth abdominal segment with 4 "teeth" (the most posterior "tooth" usually large and sharp) on each side of dorsum, and distance between caudal notch and pleural area about one-fifth to one-fourth total length of segment,

¹⁵ The characters used for separating *rufifrons* and *brightwelli* are entirely provisional. Only larval exuviae of *brightwelli* were available for examination and further study of whole larvae is necessary before better key characters can be given. The data on habitats probably are insufficient to serve as a basis of separation.

exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without seta on basal segment of labial palpus. Up to 6 (usually 3 or 4) spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions usually reaching to middorsal line on second to sixth segments, and with 5 to 10 unpaired setae in an irregular posterior transverse row.

Material used in the study of the group.—Reared material was available for *ruffifrons* and *brightwelli*. W. J. Brown, of Ottawa, identified the reared adults.

A. ruffifrons (Randall): Ten examples were examined, including the exuviae of three reared specimens. Eight of the total were from Minnesota, one from Delaware, and one from Maryland. Material associated with available reared adults is listed below.

8; Carter County, Minn.; Apr. 8, 1933; 2 adults emerged May 3, and May 4, 1933, respectively; R. Glen. (C.N.C.)
1; Centerville, Del.; Apr. 12, 1930; adult emerged May 17, 1930; C. A. Thomas. (Pa.C.)

A. brightwelli (Kirby): Only the larval exuviae of two reared specimens were available for study.

2; Cornwells, Pa.; April 1927; C. A. Thomas. (Pa.C. and C.N.C.)

A. pallidipennis Mannerheim: Eight larvae from Walla Walla, Wash., were examined. These were collected and identified by M. C. Lane. (U.S.N.M.)

ATHOUS MUTILATUS Rosenhauer

FIGURES 12, c; 34, g, h

This European species was studied from larvae collected in Germany and Denmark. Specimens collected from decaying elms were reported reared to maturity.

Larva of *A. mutilatus* are not closely allied to other known *Athous* larvae and may be distinguished by the following characters: Caudal notch large, only slightly narrowed posteriorly; urogomphi (fig. 34, g, h) with outer prongs much longer than inner prongs; outer prongs corniform, tips sharp; and abdominal mediotergites punctulate, but lacking transverse rugae and coarse pits.

The larvae examined measured up to 13 mm. in length. Dorsum pale yellow to yellowish brown with head and thorax distinctly darker. Ninth abdominal segment with 3 rounded "teeth" on each lateral margin of dorsum, and distance between caudal notch and pleural

area approximating one-sixth of total length of segment, exclusive of urogomphi. Frontoclypeal area bluntly rounded posteriorly. Without setae ventrally on basal segment of labial palpus. Third segment of antenna as long as second segment. With 3 or 4 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions extending to the middorsal suture on second to eighth segments, inclusive, and with 5 to 7 prominent setae in posterior transverse row, none definitely paired.

Material used in study.—Four larvae were examined, one from Dyrehaven, Denmark, and three from Lossnig (near Leipzig), Germany. The German specimens were labeled “reared,” but adults and larval exuviae of reared specimens were not available to the writer. (Canadian national, U. S. National Museum, and van Emden collections.)

THE ATHOUS CUCULLATUS GROUP

FIGURES 12, a; 35

KEY TO SPECIES

1. Ninth abdominal segment (fig. 35, *c*) with large deep pits on dorsum; larva usually dark brown; urogomphi with outer prongs slightly shorter than inner prongs (fig. 35, *c, d*); Manitoba and Minnesota to Atlantic coast.....**cucullatus** (Say)
- Ninth abdominal segment (fig. 35, *f*) with small, sparse punctures on dorsum; larva yellowish brown; urogomphi with prongs subequal in length 2
2. Abdominal mediotergites with the 2 most medial setae occurring close together in a definite “paired” arrangement (fig. 35, *e*); known from Illinois and Tennessee to Atlantic coast.....**scapularis** (Say)
- Abdominal mediotergites with the 2 most medial setae well separated, not more than “semipaired”; British Columbia and Alberta to California and Arizona.....**nigropilis** Motschulsky

On the basis of larval characters, the three North American species listed above have been placed in the same group, but *scapularis* and *nigropilis* are most closely allied. The larvae of all species have been identified through rearing.

These are all forest forms, the larvae occurring chiefly in decaying wood. Rearing records and adult captures indicate that pupation normally occurs in early summer, the adults being most numerous in July.

Larvae of the *cucullatus* group differ from all other known elaterid larvae in the mandible (fig. 35, *a*), which bears a prominent medial expansion in the region of the penicillus. However, the larvae may be more easily recognized by the following combination of characters: Caudal notch large (*cn*, fig. 35, *c, f*), only slightly narrowed pos-

teriorly; urogomphal prongs subequal, or inner prongs (*ipr*) longer than outer prongs, outer prongs (*opr*) with bluntly rounded tips; prominent transverse rugae on abdominal mediotergites (fig. 35, *e*), especially on third, fourth, and fifth segments.

Mature larvae usually measure 16 to 19 mm. in length. Dorsum dark brown (*cucullatus*) or yellowish brown. Ninth abdominal segment (fig. 35, *c, f*) with (*cucullatus*) or without conspicuous, large pits on dorsum, with 3 prominent "teeth" (usually blunt) on each lateral margin of dorsum, and with distance between caudal notch and pleural area approximating one-ninth to one-sixth total length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without setae on ventral aspect of basal segment of labial palpus. Up to 9 (usually 6 or 7) spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites (fig. 35, *e*) with impressions reaching to middorsal suture on some segments; transverse rugae on anterior segments give place to circular pits on posterior segments; and usually 5 or 6 prominent setae in posterior transverse row.

Material used in the study of the group.—As stated above, reared material was available for all three species. All the reared adults were identified by W. J. Brown, Ottawa.

A. cucullatus (Say): The 12 specimens examined were collected in Minnesota (1), Illinois (6), Mississippi (1), and Pennsylvania (4). In four instances larval skins were preserved with reared adults, but only one of the available whole larvae was directly associated with a reared specimen, through being collected at the same time and place. Material for which the reared adults are available is detailed below:

- 1; St. Paul, Minn.; adult emerged June 4, 1933; R. Glen. (C.N.C.)
- 1; Hummelstown, Pa.; (no date); J. N. Knull. (U.S.N.M.)
- 2; Cornwells, Pa.; April 1927; 1 reared; C. A. Thomas. (Pa.C.)
- 1; Crowell Woods, Pa.; adult emerged June 25, 1930; C. A. Thomas. (Pa.C.)

A. scapularis (Say): Nine specimens were examined. These were from Illinois (3), Tennessee (1), Maryland (1), Pennsylvania (2), and Delaware (2). The larval skins of 3 reared specimens were studied, but none of the available whole larvae were directly associated with the reared material, being from different localities. Material for which the reared adults are known to be available is listed below:

- 1; Reelfoot, Tenn.; adult emerged May 21, 1936; A. P. Arnason. (C.N.C.)
- 2; Centerville, Del.; Apr. 12, 1930; 1 adult emerged June 21, 1930, other specimens pupated June 10, 1930; C. A. Thomas. (Pa.C.)

A. nigropilis Motschulsky: Eight specimens were examined, including the exuviae of three larvae reared to adults. All were collected from the same cottonwood stump.

8; Lethbridge, Alberta; June 5, 1935; 3 reared adults emerged June 23, July 12, and July 12, respectively; R. Glen. (C.N.C.)

THE ATHOUS UNDULATUS GROUP

FIGURE 36

KEY TO SPECIES

- Urogomphi (fig. 36, *a*) with outer prongs slightly shorter than inner prongs; dorsum of ninth abdominal segment with conspicuous pits anteriorly; mesothorax and metathorax with well-developed impressions on mediotergites.....*A. undulatus* (DeGeer)
- Urogomphi (fig. 36, *d*) with prongs subequal; dorsum of ninth abdominal segment with conspicuous pits both posteriorly and anteriorly; mesothorax and metathorax with very short impressions on mediotergites...
.....*A. villosus* (Geoffroy)

The larvae of *Athous* (*Harminius*) *undulatus* (DeGeer) and *Athous villosus* (Geoffroy) (= *A. rhombeus* Olivier) are sufficiently closely allied to be placed in the same group until the larvae of other related species are available for examination. Both species occur in Europe and *undulatus* is reported by Van Dyke (1932, p. 368) also to inhabit the Hudson Bay and Lake Superior regions of North America. The larvae are found in decaying wood and are believed to be predaceous.

Larvae of this group superficially resemble those of *Athous cucullatus* (Say), but differ in characters of the mandible, sculpture of abdominal mediotergites (fig. 36, *c*), and shape of the caudal notch (fig. 36, *a, d*).

Mature larvae usually exceed 20 mm. in length. Dorsum is dark brown to brownish black, with large, deep pits, sometimes confluent in second to sixth segments. Venter pale yellow. Caudal notch at least moderately large, subcircular, much narrowed posteriorly. Urogomphi (fig. 36, *a, b, d, e*) with subequal prongs, or with inner prongs longer than outer prongs; outer prongs (*opr*) with bluntly rounded tips. Ninth abdominal segment with large, deep pits on dorsum; sometimes (*villosus*) with 2 fine setae anteriorly on dorsal plate; with 3 prominent blunt teeth on each lateral margin of dorsum; and distance between caudal notch and pleural area approximating one-eighth of total length of segment, exclusive of urogomphi. Frontoclypeal area truncate (*villosus*) or broadly rounded (*undulatus*) posteriorly. Man-

dible without medial expansion in region of penicillus (thus differing from *A. cucullatus* group, fig. 35, *a*). Without setae on ventral surface of basal segment of labial palpus. Up to 5 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites (fig. 36, *c*) with impressions of variable length, sometimes appearing to extend to middorsal suture on second to fifth segments, but usually difficult to distinguish impressions from confluent adjoining pits; from 6 to 10 setae in posterior transverse row, usually some arranged in pairs.

Material used in the study of the group.—*A. undulatus* (DeGeer): Four larvae from Finland were examined. The larva of this species has been known in Europe for many years and the writer believes that this material is reliably identified although probably not directly associated with reared specimens. (C.N.C. and U.S.N.M.)

A. villosus (Geoffroy): Four specimens from Denmark were examined, including the exuvium of one specimen said to have been reared. The adult of this specimen was not available to the writer, but the label stated "adult det. by August West." It is also known that August West (1937, p. 484) has reared the larva of *Athous villosus* from Dyrehaven, Denmark.

1; Bognaes, Denmark; (no date); reared; J. P. Kryger (U.S.N.M.; adult probably in A. West's collection, Denmark).

Other specimens examined are deposited in the Canadian national and the U. S. National Museum collections.

Genus HEMICREPIDIUS Germar

FIGURES 12, *d, f*; 37, *a-c*

Species of *Hemicrepidius* are commonly recorded in the older North American literature under the generic name *Asaphes* Kirby.

Characters of this genus have been based upon the larvae of *H. memnonius* (Herbst), *H. hemipodus* (Say) (= *decoloratus* Say), *H. bilobatus* (Say), *H. carbonatus* (LeConte), and a larva, the reared adult of which was identified as "*Hemicrepidius* sp. near *carbonatus* (LeConte)." Larvae of the European *Athous niger* (Linnaeus) and a larva which might be *Athous hirtus* (Herbst) have been included with *Hemicrepidius* in the present discussion since these possess typical *Hemicrepidius* characters.

H. hemipodus and *H. carbonatus* are the only American species that have been collected in numbers suitable for adequate characterization of their larvae. Other species seem to be rare, with the re-

sult that single specimens are taken and reared to adults leaving only the larval exuviae for examination. Additional material and further study are required for sound selection of key characters and for the definition of "species groups" within the genus.

A single larva of *Hemicrepidius* sp. was collected from a decaying cottonwood stump on the banks of the Old Man River at Lethbridge, Alberta. Decaying wood may be the typical habitat of this species, but the larvae of the other species are known to be primarily soil inhabiting, preferring moist soils such as woodland meadows and only rarely occurring in forest litter or in decaying wood.

H. memnonius (Herbst) has been reared from a New Brunswick garden, and from leaf litter in Pennsylvania. However, the species is recorded as far west as Alberta. *H. bilobatus* (Say) and *H. hemipodus* (Say) appear to be more truly eastern, not being recorded from west of the Great Lakes.

H. hemipodus is the only species commonly encountered in the larval stage. It has been taken from cornfields and other cultivated or pasture land from Maine to Illinois, but apparently it does not cause very severe crop injury. Forbes (1892, p. 39) suggests that this may be due in part to the early date at which larval activity ceases, pupation occurring normally in May or June. The newly formed adults appear to leave their pupal cells immediately. Similar habits of pupation and adult emergence are reported (Henriksen, 1911, p. 274) for *Athous niger*, and rearing records of other *Hemicrepidius* larvae indicate that pupation normally occurs relatively early in the summer. This biological character is common to *Hemicrepidius*, *Lep-turooides*, several American species of *Athous*, and possibly *Elathous*. However, Blatchley (1910, p. 770) reports finding adults of *H. memnonius* in Indiana from June 8 to December 27, hibernation occurring beneath the bark of red oak logs.

On the basis of larval structure, *Hemicrepidius* is very closely related to *Athous*. Distinction is most readily obtained through the absence of eyes in *Hemicrepidius*. Other important characters are: Dorsum yellowish brown, never dark brown; large caudal notch; urogomphal prongs (fig. 37, c) subequal, or outer prongs slightly longer; abdominal mediotergites (fig. 37, b) with conspicuous transverse rugae, and with impressions reaching to middorsal suture in some segments. The urogomphal prongs show considerable individual variation; in typical specimens each prong has a short, sharp tip, but this is frequently worn away, especially on the outer prongs, giving them the smooth, rounded appearance found in *Athous cucullatus* (Say) and its allies.

Only large and moderate-sized species are known, the mature larvae usually exceeding 20 mm. in length. Dorsum of ninth abdominal segment (fig. 37, *c*) with median dorsal groove (*mg*), without setae on the central area, frequently with noticeable pits, and with 3 or 4 prominent "teeth" (*to*) on each lateral margin. Nasale tridentate at tip. Subnasale of many fine teeth. Two unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible (fig. 37, *a*) usually with relatively short retinaculum (*ret*). Presternum of prothorax undivided. Mesothorax and metathorax with distinct impressions on mediotergites, and up to 8 spinelike setae on each episternum. Each abdominal mediotergite with 5 or more prominent, unpaired setae in posterior row.

PROVISIONAL KEY TO SPECIES OF HEMICREPIDIUS

- | | |
|--|--------------------------------|
| 1. From Europe | 2 |
| From North America..... | 3 |
| 2. Distance between caudal notch and pleural area of ninth abdominal segment about one-seventh total length of segment, exclusive of urogomphi; frontoclypeal area almost pointed posteriorly..... | |
| <i>Athous hirtus</i> (Herbst) (?) | |
| Distance between caudal notch and pleural area about one-fifth length of segment; frontoclypeal area truncate posteriorly..... | |
| <i>Athous niger</i> (Linnaeus) | |
| 3. Inhabiting rotten wood; collected at Lethbridge, Alberta..... | |
| <i>Hemicrepidius</i> sp., near <i>carbonatus</i> (LeConte) | |
| Inhabiting soil, rarely in forest litter..... | 4 |
| 4. Basal segment of labial palpus with small seta ventrally; western North America (larvae from Walla Walla, Wash.)..... | |
| <i>H. carbonatus</i> (LeConte) | |
| Basal segment of labial palpus without seta; east of Rocky Mountains... | |
| | { |
| ..... | { <i>H. memnonius</i> (Herbst) |
| ..... | { <i>H. hemipodus</i> (Say) |
| ..... | { <i>H. bilobatus</i> (Say) |

Material used in study of the genus.—Reared adults of the following species of *Hemicrepidius* have been identified by W. J. Brown, of Ottawa: *memnonius* (Herbst), *hemipodus* (Say), *bilobatus* (Say), and "*Hemicrepidius* sp., near *carbonatus* (LeConte)." Reared material was also available of *Athous niger* (Linnaeus).

H. memnonius (Herbst): The larval exuviae of 3 reared specimens were examined, but no reliably named whole larvae were available.

2; Fredericton, New Brunswick; (no date); both reared; R. P. Gorham. (C.N.C.)

1; Cornwallis, Pa.; April 1927; reared; C. A. Thomas. (Pa.C.)

H. hemipodus (Say): Eight examples were studied, including the exuviae of four reared specimens. Unfortunately, the reared specimens were not collected at the same time and place as the whole larvae that were available.

1; Orono, Maine; Aug. 1, 1929; reared; J. H. Hawkins. (U.S.N.M.)
3; Downingtown, Pa.; Apr. 10, 1930; adults emerged May 13, June 2, June 12, 1930; C. A. Thomas. (Pa.C.)

H. bilobatus (Say): Only the exuvium of 1 reared specimen was studied.

1; Hulmeville, Pa.; Apr. 13, 1927; reared; C. A. Thomas. (Pa.C.)

H. carbonatus (LeConte): Eight larvae were examined. These were collected at Walla Walla, Wash., by M. C. Lane and identified by him. (U.S.N.M.)

Hemicrepidius sp., near *carbonatus* (LeConte): Only the exuvium of one reared specimen was available.

1; Lethbridge, Alberta; June 5, 1935; adult emerged July 12, 1935; R. Glen. (C.N.C.)

Athous niger (Linnaeus): Seven specimens were studied, including the exuviae of two that were reared. None of the whole larvae was from the same collection as the reared material, but specimens were examined that were used by K. L. Henriksen (1911) in his description of this species. The material was from Denmark (5), Holland (1), and Germany (1). (U.S.N.M.)

2; Denmark; 1895; both reared; A. Ditlevsen. (R.V.A.C.)

Athous hirtus (Herbst)(?): Examination of this species was limited to a single specimen from France labeled as "*Athous hirtus* Hbst. or *niger* L.?" This larva differed slightly from available specimens of *A. niger*. (van Emden.)

Genus CREPIDOMENUS Erichson

CREPIDOMENUS QUEENSLANDICUS Blair

FIGURES 10, f; 37, d-f

This Australian species is the only *Crepidomenus* known in the larval stage. Specimens were received for study through the courtesy of W. A. McDougall, Assistant Entomologist, Central Sugar Experi-

ment Station, Mackay, Queensland, and from the British Museum of Natural History, London.

According to McDougall (1934, pp. 60, 65, 67; "*B sp.*") the larvae inhabit the soil of cultivated fields and grasslands; feeding normally occurs only during short periods immediately after each ecdysis; the complete larval life is probably less than 1 calendar year; and pupation occurs in September or early October, the adults being found in greatest numbers as early as the middle of October.

In structure, the larva of *C. queenslandicus* resembles the larvae of the genus *Cryptohypnus*, particularly in possessing dorsal postero-epicranial setae (as in fig. 10, *g, ped*), and medial anterotergal setae (*atm*, figs. 10, *g*; 37, *d*) in thorax and abdomen. It is distinguished by the following characters: Dorsum of ninth abdominal segment (fig. 37, *e, f*) with sharp "teeth" (*to*) on the lateral margins, and only 2 setae on the central area; abdominal mediotergites (fig. 37, *d*) with long impressions and lacking seta number 7 as numbered in *Cryptohypnus* (fig. 38, *f*).

Larvae examined measured up to 19 mm. in length; dorsum yellowish brown to pale chestnut brown; rather densely set with small punctures. Caudal notch large, not narrowed posteriorly. Urogomphi (*ur*, fig. 37, *e, f*) usually with prongs subequal in length, inner prongs (*ipr*) sometimes longer and always slightly more robust than outer prongs (*opr*). Ninth abdominal segment (fig. 37, *e, f*) without median dorsal groove, and distance between pleural area and caudal notch approximating one-fifth to one-fourth length of segment, exclusive of urogomphi. Nasale with tridentate tip, lateral denticles only slightly smaller than median denticle. Frontoclypeal area rounded posteriorly. Eyes present; surrounded by 4 setae. Three unpaired lateroepicranial setae on each gena. Gula moderately long, but very narrow. One "sensory" appendix on second segment of antenna. Mandible with prominent retinaculum. Presternum of prothorax divided, the median posterior piece being small. Mesothorax and metathorax with distinct impressions on mediotergites, and without spine-like setae on episterna. Abdominal mediotergites (fig. 37, *d*) with transverse branches of impressions reaching four-fifths to five-sixths of distance from longitudinal branches to middorsal suture. Abdominal pleurites large, subequal from first to eighth segments.

Material used in study.—Thirty larvae were examined. All were collected at Mackay, Queensland, by W. A. McDougall, who succeeded in rearing this species. (C.N.C. and B.M.)

Genus *CRYPTOHYPNUS* EschscholtzFIGURES 10, *g*; 38

The name *Cryptohypnus* has been used in the present study for species which, on the basis of larval characters, obviously are allied to *Cryptohypnus riparius* (Fabricius) (= *Hypnoidus riparius*), and for which American authors recently have shown a preference for the generic name *Hypolithus* Eschscholtz. The name *Hypnoidus* Stephens is restricted to species whose larval characters stamp them as being congeneric with *H. dubius* (Horn) and generically distinct from *riparius* and its close allies.

Characters given for this genus are based upon a study of the larvae of the five species listed in the key. All are believed to be soil inhabiting, and some are important crop pests.

These larvae superficially resemble *Melanactes densus* and the *Ludius nitidulus* group but are much more closely allied to the genus *Crepidomenus*. *Cryptohypnus* larvae are distinguished by a combination of characters involving setal arrangement, sculpture, and features of the ninth abdominal segment, the following being of primary significance: Head bearing dorsal posteroepicranial setae (*ped*, figs. 10, *g*; 38, *a*); each thoracic segment and first 8 abdominal segments bearing medial anterotergal setae (*atm*, figs. 10, *g*; 38, *f*); abdominal mediotergites with impressions and setal pattern as in figure 38, *f*, setae numbered 1 to 9 being present in all species; dorsum of ninth abdominal segment (fig. 38, *i*) bearing 4 setae on central plate and blunt "teeth" (*to*) on the margins.

The species studied rarely exceed 16 mm. in length. Dorsum yellow to yellowish brown; finely punctulate. Caudal notch (*cn*) large. Urogomphi bifid, prongs subequal in length (fig. 38, *e*, *g*) or inner prongs longer (fig. 38, *h*, *i*). Ninth abdominal segment without median dorsal groove, and distance between pleural area and caudal notch varies from one-sixth to one-fourth length of segment, exclusive of urogomphi. Nasale (*n*, fig. 38, *b-d*) typically tridentate; lateral denticles may be serrate (fig. 38, *d*) or absent through erosion. Eyes present. Gula moderately narrow. One "sensory" appendix on second segment of antenna. Mandibles of same type as in *Ludius aeriipennis*. Presternum of prothorax of more than 1 piece, the median posterior sclerite being very narrow and often indistinct. Mesothorax and metathorax with distinct impressions on mediotergites; and with 1 to 3 setae on each episternum, setae usually fine or with only 1 being spinelike. Abdominal pleurites well developed, decreasing in size from first to eighth segments.

KEY TO SPECIES OF CRYPTOHYPNUS

1. Urogomphal prongs subequal (fig. 38, *e, g*); eastern North America....
.....*abbreviatus* (Say) (p. 185)
Inner prongs of urogomphi longer than outer prongs (fig. 38, *h, i*).... 2
2. Nasale (*n*, fig. 38, *d*) with several small denticles on each side of base of
median tooth; western North America....*funebri* Candeze (p. 185)
Nasale (*n*, fig. 38, *b*) tridentate, lateral denticles sometimes absent
through erosion..... (the *riparius* group, p. 184) 3
3. From Europe.....*riparius* (Fabricius)
From North America..... 4
4. Basal segment of labial palpus with 1 seta ventrally.....*sanborni* Horn
Basal segment of labial palpus without setae.....*nocturnus* (Eschscholtz)

THE CRYPTOHYPNUS RIPARIUS GROUP

FIGURES 10, *g*; 38, *b, h, i*

Included in this group are *riparius* (Fabricius), *nocturnus* (Eschscholtz), and *sanborni* Horn. All live in the soil. *C. nocturnus* is reported by King (1928, pp. 703-704) as an important pest of grain crops in Saskatchewan, and Evans (1921) suggests that *riparius* might injure field crops in Scotland.

This is a very homogeneous group, well characterized by the urogomphi and caudal notch (fig. 38, *h, i*) and by the nasale and subnasale (fig. 38, *b*).

These larvae seldom exceed 13 mm. in length. The inner prongs of the urogomphi are about twice as long as the outer prongs; the tips of the outer prongs turn slightly inward. The large, U-shaped caudal notch is not narrowed posteriorly except in a few atypical specimens. In the tridentate nasale, the lateral denticles are often weakly developed and sometimes are eroded away, giving a unidentate appearance. The frontoclypeal area is broadly rounded posteriorly.

Material used in the study of the group.—*C. riparius* (Fabricius): Eight larvae were examined. These were from Denmark (5), Finland (1), Russia (1), and Ireland (1). The specimens studied are believed to be reliably named, because the larva of this species is well known in Europe and some of the available material was used by K. L. Henriksen (1911) in his description of this species. (B.M. and U.S.N.M.)

C. nocturnus (Eschscholtz): Thirteen examples were studied, including the exuviae of four reared specimens. The reared adults were identified by W. J. Brown, of Ottawa.

10; Barnwell, Alberta; June 6, 1935; 2 adults emerged Aug. 8 and Aug. 9, 1935; R. Glen. (C.N.C.)

- 1; Taber, Alberta; June 6, 1935; adult emerged Jan. 31, 1936; R. Glen and G. F. Manson. (C.N.C.)
2; Turtleford, Saskatchewan; June 10, 1937; 1 adult emerged Aug. 3, 1937; J. V. Brooks. (C.N.C.)

C. sanborni Horn: Twenty specimens were studied, all from Churchill, Manitoba. A reared adult was identified by W. J. Brown, of Ottawa.

- 20; Churchill, Manitoba; June and July 1937; 1 adult emerged in July 1937; W. J. Brown. (C.N.C.)

CRYPTOHYPNUS FUNEBRIS Candeze

FIGURE 38, *d, f*

This western species is distinguished by the numerous denticles on nasale and subnasale (fig. 38, *d*), and by the frontoclypeal area, which is bluntly pointed posteriorly. The caudal notch is U-shaped and is not narrowed posteriorly. The urogomphi have the inner prongs longer than the outer prongs but less than twice as long. The setal pattern on abdominal mediotergites is given in figure 38, *f*. Larvae of this species are larger than other known *Cryptohypnus*, those at hand measuring about 16 mm. in length.

Material used in study.—Only 2 larvae were available for examination. These were collected, along with adults of this species, at Walla Walla, Wash., by M. C. Lane, and identified by him. It is not known that larvae of this type have actually been reared to adults, but Mr. Lane has expressed his confidence in the identification made. (U.S.N.M.)

CRYPTOHYPNUS ABBREVIATUS (Say)

FIGURE 38, *a, c, e, g*

This species is widely distributed in the eastern United States and from Newfoundland as far west as Saskatchewan. It is an important pest in fields and gardens. The larva differs from other known *Cryptohypnus* in having the urogomphal prongs (fig. 38, *e, g*) subequal; the caudal notch subcircular, or transversely subovate, and considerably narrowed posteriorly; the subnasale (fig. 38, *c*) with about 7 or 8 denticles; and the frontoclypeal area (fig. 38, *a*) rounded posteriorly. The lateral denticles of nasale are sometimes eroded, giving the appearance of a unidentate structure. Fully distended mature larvae measure up to 12 mm. in length.

Material used in study.—Examination was made of 12 examples, including the exuviae of 4 reared specimens. The reared adults were identified by W. J. Brown, of Ottawa.

- 3; Rhein, Saskatchewan; June 11, 1930; 2 adults emerged July 21 and Aug. 6, 1930; E. Mengerling. (C.N.C.)
9; Spencerville, Grenville County, Ontario; June 23, 1938; 2 adults emerged Aug. 26 and Sept. 2, 1938; G. H. Hammond. (C.N.C.)

Genus HYPNOIDUS Stephens

FIGURES 9, *f*; 10, *b*; 39

The name *Hypnoidus* is used here in the restricted sense and does not include the species which are commonly referred to the genus *Cryptohypnus*.

Knowledge of this genus is based upon an examination of larvae of *dubius* (Horn), *musculus* (Eschscholtz), and the European *maritimus* Curtis. These species are very similar and it might be that they represent only one group within the genus. All are believed to be soil inhabiting and *dubius* is recorded by King (1928, p. 705) as being of economic importance in Saskatchewan. Kincaid (1900, pp. 374-375) described the larva of *musculus* from Alaska.

The known *Hypnoidus* larvae rarely exceed 11 mm. in length, are very pale yellow in color and are readily identified by the absence of spinelike setae on the coxae (fig. 39, *e*), by the mandibles (fig. 39, *c*, *g*) and by the pointed, undivided urogomphi (fig. 39, *f*, *h*, *i*). Sometimes, especially in *musculus*, a slight tubercle is present on the latero-posterior aspect of each urogomphus, which might be interpreted as an extremely small outer prong.

The caudal notch (*cn*) is large, usually transversely ovate and more or less narrowed posteriorly. The ninth abdominal segment lacks the transverse impression, the median sulcus, and the "teeth" on lateral margins, but bears 4 setae on central dorsal area. Nasale (*n*, fig. 39, *a*) consists of 3 short, subequal teeth, lateral denticles somewhat serrate in *maritimus*. Frontoclypeal area pointed posteriorly. Eyes lacking. Gula (fig. 39, *b*) very long and narrow. One "sensory" appendix on second segment of antenna. Galea reduced to a single segment. Mandible (fig. 39, *c*, *g*) with small retinaculum (*ret*), and finely serrate posterior to base of retinaculum. No distinct impressions on mediotergites of mesothorax and metathorax. Without spinelike setae on thoracic episterna. Abdominal mediotergites slightly rugose,

not punctured, impressions indistinct, and prominent setae unpaired. Abdominal pleurites (*pl*, fig. 39, *d*) large, sterna (*st*) undivided.

PROVISIONAL KEY TO SPECIES OF HYPNOIDUS

1. From North America..... 2
 From Europe *maritimus* Curtis
2. Mandible (fig. 39, *g*) usually with about 5 or 6 fine denticles at base of retinaculum *musculus* (Eschscholtz)
 Mandible (fig. 39, *c*) usually with about 2 fine denticles at base of retinaculum *dubius* (Horn)

Material used in study of the genus.—Reared adults of *H. dubius* (Horn) and *H. musculus* (Eschscholtz) were identified by W. J. Brown, of Ottawa.

H. dubius (Horn): Six specimens from Saskatoon, Saskatchewan, were examined, including the exuvium of one reared specimen. (C.N.C).

1; Saskatoon, Saskatchewan; May 27, 1924; adult emerged June 25, 1924. K. M. King.

H. musculus (Eschscholtz): Four larvae were studied. These were collected by T. Kincaid from Popoff Island, Alaska, and were the specimens upon which he based his description. An adult which was reared from a larva apparently collected at the same time and place is in the U.S. National Museum, but the associated larval skin could not be found.

H. maritimus Curtis: Six larvae from Austria were examined. These were identified through field association with adults of this species. However, the larvae show typical *Hypnoidus* characters and there is good reason to believe that the identification probably is correct. (Canadian national and British Museum collections.)

Genus *EANUS* LeConte

FIGURE 40, *a-c*

Species of *Eanus* are commonly recorded in the European literature under the generic name *Paranomus* Kiesenwetter.

Larvae of this group inhabit the litter of the northern and alpine forests and are probably chiefly predaceous. *E. decoratus* has been reared from Quebec and larvae have been collected as far west as Saskatchewan. According to Brown (1930, p. 163) adults of this species are known from the Gulf of St. Lawrence to Alaska. A larva

believed to be *E. costalis* was described from Finland by Prof. U. Saalas (1937, pp. 68-72, "Probably *Orithales serraticornis* Payk.,"; 1938, pp. 53-55), who kindly loaned the writer material for examination.

These two species are very similar in structure and are most readily separated on the basis of geographic distribution. However, Brown (1930, p. 162) has indicated that they represent only one of the two distinct species groups included in the genus. On the basis of the larvae examined, *Eanus* is an isolated genus, readily distinguished by the following characters: Dorsum of ninth abdominal segment (fig. 40, *d, e*) strongly convex, and without raised lateral margins; urogomphus (*ur*) undivided, blunt, and with a strongly sclerotized bar on inner aspect; abdominal pleurites absent or practically so (fig. 40, *b, c*); abdominal mediotergites (*mtg*, fig. 40, *b*) with very faint, short impressions, and with only 3 prominent unpaired setae in the posterior transverse row.

Eanus larvae are pale yellow; up to 18 mm. in length; with inconspicuous sculpture. Ninth abdominal segment with small caudal notch, and distance between pleural area and caudal notch about one-fifth length of segment, exclusive of urogomphi. Nasale of 1 sharp tooth. Eyes present; bordered by 2 unpaired setae. Two unpaired lateroepicranial setae on each gena. Gula extremely narrow, area practically closed posteriorly. One "sensory" appendix on second segment of antenna. Mandible (fig. 40, *a*) very robust with toothlike expansion of dorsal margin of inner face of distal half. Presternum of prothorax divided, the posterior median piece being very small. Mesothorax and metathorax with faint but definite impressions on mediotergites, and without spinelike setae on episterna.

Material used in study of the genus.—*E. decoratus* (Mannerheim): Eleven examples were examined, including the exuviae of three reared specimens. All were from the province of Quebec and the reared adults were identified by W. J. Brown, of Ottawa. (C.N.C.) Material identified through rearing is listed below:

- 1; Mount Lyell, Gaspé County, Quebec, 1,500 ft.; (no date); adult found emerged on Oct. 1, 1934; C. C. Smith. (C.N.C.)
- 2; Cascapectia River, Quebec; adults emerged Sept. 7 and Sept. 20, 1935; M. L. Prebble. (C.N.C.)

E. costalis (Paykull) (?): One larva from Suomussalmi, Finland, was all the material available for examination. This was an unidentified specimen that is believed to be *E. costalis* because of its morpho-

logical similarity to *E. decoratus* larvae and because *E. costalis* inhabits Finland. On the basis of adult characters, Brown (1930) reported these two species to be very closely related. The larva examined is the property of Prof. U. Saalas, Helsinki, Finland.

Genus **MELANACTES** LeConte

MELANACTES DENSUS LeConte

FIGURE 40, *f*

Melanactes densus is the only species of this genus that is known in the larval stage. It is a western species, but the natural habitat of the larva is unknown, the only specimen available for examination being reared from eggs laid in captivity.

On the basis of larval characters this species is a typical member of the tribe Lepturoidini and should not be separated into a distinct tribe as arranged by Leng (1920). Superficial resemblances are found in the larvae of *Hemicrepidius*, *Crepidomenus*, and *Cryptohypnus*, but no closely related genera are known. The larva of *M. densus* (fig. 40, *f*) is readily distinguished by its large size, absence of eyes, setal and sculptural patterns, shape of the caudal notch, and the urogomphi in which the inner prongs are small and the outer prongs very long and corniform. The larva hitherto regarded by some writers as *Melanactes piceus* (DeGeer), originally figured by Riley and reproduced by Blatchley (1910, p. 771, fig. 292), unquestionably is not a *Melanactes* larva or the larva of any other elaterid.

The larva examined was not fully distended, but measured 38 mm. in length and 4.75 mm. in breadth at 5 years of age. Fully distended mature larvae undoubtedly would exceed 40 mm. Dorsum golden brown; venter paler; lateral membranes large, creamy white. Caudal notch large, transverse. Urogomphi short, robust, bifid; prongs corniform, with sharp upturned tips; outer prongs 3 to 4 times as long as inner prongs. Ninth abdominal segment without a mediodorsal groove, but with a shallow subcircular depression bearing 2 faint, short, paramedian impressions; 4 widely separated setae on central dorsal area, posterior setae being longer; 3 blunt "teeth" on each lateral margin of dorsal plate; tergite continues uninterruptedly on posterior ventral surface for a distance approximating one-eighteenth total length of segment exclusive of urogomphi; sternum large, consisting of 2 sclerites separated anteriorly by a narrow median suture. Nasale of 1 tridentate tooth, median denticle slightly larger than lateral denticles. Frontoclypeal region broadly rounded posteriorly. One small dorsal posteroepicranial seta just laterad to each side of posterior part of

frons. Eyes absent. With 4 setae surrounding each eye region. Two unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with well-developed retinaculum. Presternum of prothorax undivided, but may be deeply incised laterally near apex, almost separating off a small, narrow, posterior median sclerite. Mesothorax and metathorax with prominent long impressions, up to 7 spinelike setae on each episternum. Abdominal mediotergites with impressions reaching to middorsal suture; first to seventh segments with conspicuous transverse rugae, eighth segment with pits more nearly circular; 1 anterior mediotergal seta present on each mediotergite; conspicuous setae unpaired on anterior part of segments, but approaching a semipaired arrangement in posterior transverse row. Abdominal pleurites large, decreasing in size from first to eighth segments. Spiracles noticeably widened anteriorly, subpyriform; situated in anterior part of segments.

Material used in study.—The only specimen available for examination was a 5-year-old larva received through the courtesy of Dr. W. H. Anderson, U. S. Bureau of Entomology and Plant Quarantine, Washington, D. C.

1; Huntington Beach, Calif.; reared from eggs that hatched June 3, 1935; M. W. Stone. (U.S.N.M.)

SUMMARY OF TAXONOMIC RELATIONSHIPS

In the Lepturoidini, relationships based upon larval characters agree closely with those founded upon careful study of the adults. Recognized subspecies are morphologically indistinguishable in the larval stage; closely allied species appear to be more readily distinguished as adults than as larvae, as evidenced by the species of *Ludius* included in the *cupreus* group and the *aeripennis* group; but group relationships are revealed as clearly by the larvae as by the adults. The evidence from larval studies should be considered in taxonomic revisions. However, such evidence must be used with exceeding care, because it is based upon a very small proportion of the existing species.

Rightly or wrongly, at the beginning of this study the type species were looked upon as the ultimate criteria for the determination of generic status. It was believed that any given larva could be classified to genus by comparing it with genotype material. In practice this proved futile, especially for large genera, because only a very small proportion of the available species of each large "genus" bore evident close relationship to the genotype. The supraspecific unit that stood out clearly as a measure of relationship was the "species group,"

DIAGRAM OF GENERAL RELATIONSHIPS BETWEEN LEPTUROIDINE GENERA
AND "SPECIES GROUPS" OF *LUDIUS*

Species above the broken transverse line have the nasale single-pointed; species below this line have the nasale triple-pointed, except in *Limonius pilosus* (Leske). Genera in parentheses have the urogomphi simple; all others have the urogomphi bifid. The spacing suggests the degree of relationship, and possible annectant groups are indicated by connecting lines.

	CAUDAL NOTCH LARGE	CAUDAL NOTCH SMALL
PROSTERNUM DIVIDED (nasale unidentate)	II	I
	rotundicollis	(<i>EANUS</i>)
	bipustulatus	
	propola	appressus
	inflatus aeripennis	cupreus
	semivittatus edwardsi	
	fallax	
	nitidulus	
	CRYPTO- HYPNUS	sjaelandicus
	CREPI- DOMENUS	
PROSTERNUM UNDIVIDED (nasale tridentate)	IV	III
<i>MELANACTES</i>	pyrrhos	limoniiformis
<i>HEMICREPIDIUS</i> --- <i>ATHOUS</i> (cucullatus) (undulatus) (mutilatus)		resplendens
divaricatus		ELATHOUS---LIMONIUS
(<i>HYPNOIDUS</i>)		ATHOUS---LEPTUROIDES (vittatus) (rufifrons)

of which several to many were apparent within each of the larger genera as recognized in the current taxonomic literature. In effect, each genotype was representative of but one "species group."

Some of the larger genera are too complex to be adequately characterized. This is particularly true of *Ludius* and *Athous* and to a lesser degree of *Limonius*. On the basis of the material studied, the following genera appear to be sufficiently homogeneous to permit of characterization: *Crepidomenus*, *Cryptohypnus*, *Hypnoidus*, *Eanus*, *Elathous*, *Lepturoides*, *Hemicrepidius*, and *Melanactes*. However, larvae of only one to five species were available for each of these genera and insufficient representation may account for this apparent homogeneity.

In general, the taxonomic value of any character or set of characters changes from one "species group" to another. However, throughout the tribe studied certain characters have maintained a high ordinal value. Simple urogomphi and bifid urogomphi have not been found within the same genus; and the type of caudal notch, the general type of prosternum, and the general type of nasale have varied comparatively little between species of the same "species group." Accordingly, these are regarded as primary group characters, their relative importance being as in the order stated. On the basis of these characters the general relationships between the "species groups" of *Ludius* and the other lepturoidine genera are charted on page 191.

THE GENUS LUDIUS

The "species groups" of *Ludius* that have been erected on the basis of larval characters agree closely with those independently established by Brown (1935, 1936, 1939), who studied the adults of the American species. Where adequate larval material was available, Brown's groups were invariably substantiated, but where the larvae of only a very few species were known or where the material was not suitable for a complete examination, the larval study suggested fewer groups than Brown had erected. The writer agrees completely with the following statement (Brown, 1935a, p. 1): "The genus *Ludius*, as now recognized in the American literature, is not a true genus in any natural sense, but is, rather, a heterogeneous group of species the natural affinities of which are not known." Similar conclusions have been reported by Blatchley (1910, p. 763) and by Van Dyke (1932, pp. 389-390), who studied the adults, and by Henriksen (1911, p. 258), who described the larvae of seven species.

Brown has done much toward establishing the natural affinities of many of the species now included in the genus. However, no proposals have yet been made for reducing the genus to a more homogeneous assemblage. The larval record is much too incomplete to form a basis for sound revision. In fact, since only 10 percent of the species are known in the larval stage, it is dangerous even to attempt an appraisal of specific relationships. However, a brief appraisal of the larval evidence is presented with the hope that it might encourage further efforts in this direction.

The 44 species of *Ludius* studied have been arranged into 17 distinct "species groups," some groups being represented by a single species. For purposes of identification, these groups are best considered in the four major sections (I, II, III, IV) shown on page 191. However, the natural affinities of *Ludius sjaelandicus* (Müller) are believed to lie nearer to several species in section III than to the other species in section I. Within section II some of the "species groups" are very closely related, e.g., *inflatus* and *aeripennis*, *semivittatus* and *edwardsi*; whereas *propola*, *triundulatus*, and *fallax* are not quite so closely allied; and *bipustulatus*, *rotundicollis*, and *nitidulus* are relatively isolated. In contrast, the *Ludius* species that fall in section III are not more closely related to one another than are the recognized genera *Elathous*, *Limonius*, *Athous* (pars), and *Lepturoides*, which also fall in that section.

The larval characters suggest that for taxonomic purposes the genus *Ludius* might be revised by making the following subdivisions (genera ?):

- SUBDIVISION 1: the *cupreus* and *appressus* groups; the relationships of *appressus* (Randall) seem to lie with *cupreus*.
- SUBDIVISION 2: all *Ludius* included in section II; the *nitidulus* group might form the nucleus of a distinct subdivision connecting with the genera *Cryptohypnus* and *Crepidomenus*.
- SUBDIVISION 3: *L. divaricatus* (LeConte) and its allies; this is an isolated species without close affinities to any known group in the Lepturoidini.
- SUBDIVISION 4: *L. sjaelandicus* (Müller) and allied species, if any exist.
- SUBDIVISION 5: the *pyrrhos* group.
- SUBDIVISION 6: the *limoniiformis* group.
- SUBDIVISION 7: *L. resplendens* (Eschscholtz) and its allies; the possibility of removing *resplendens* to the genus *Elathous* warrants consideration.

Subdivisions 4 and 5 have a somewhat common bond in the unusual condition of the spiracles in the eighth abdominal segment, and in setal and sculptural characters. Likewise, subdivisions 4, 5, 6, and 7 all have the urogoniphial prongs subequal and certain other characters in

common. However, the union of two or more of these groups produces an assemblage that cannot be adequately characterized to permit ready separation from the other genera included in section III of the diagram on page 191.

This attempt to reduce the genus *Ludius* to definable limits is merely suggestive. The larval record is too incomplete to provide the necessary perspective, but it might supplement the evidence from adult studies. There are two alternatives to the suggested subdivisions given above: make every "species group" a new genus, or leave the genus in its present indefinable state. From the purely phylogenetic viewpoint, it is doubtful if genera are completely definable. Therefore group limits for taxonomic purposes are very difficult to draw.

Species seem to be well defined in those parts of the genus that Brown has revised. His species have been substantiated wherever adequate larval material was available for study. However, very detailed examination frequently was necessary to discover the separating characters of closely allied forms. Brown's species concept appears to be valid, but any narrower concept could not be supported by larval evidence. As more material becomes available, it is quite possible that larval characters will not be found to separate all species that Brown has recognized. Such a result can be expected, since distinctions that are evident in the definitive adults might be obscured in the developmental stages.

Ludius rotundicollis (Say), as currently recognized, appears to include more than one species. The larvae from the eastern States and those from the western States are morphologically distinct and, therefore, should be considered as distinct species.

THE ATHOUS COMPLEX

In contrast to the genus *Ludius*—which has been allowed to develop into an indefinable assemblage—other parts of the Lepturoidini have been separated into smaller, closely related genera. Thus *Elathous*, *Hemicrepidius*, and *Lepturoides* are very closely allied to the genus *Athous* as recognized at present, but *Athous* itself is polymorphic. As illustrated on page 191, sections III and IV, *Athous* consists of two main parts which are less closely related to each other than to other established genera. The failure of European workers to recognize the genus *Hemicrepidius* in their fauna is due to its similarity to *Athous*. The European *Athous niger* (Linnaeus) and its allies are typically *Hemicrepidius*. Whether *Hemicrepidius*

should be recognized as a genus or merely as one or more "species groups" under *Athous* is open to question. On the basis of larval characters *Hemicrepidius* is not more distinct from *Athous* than are the "species groups" of *Athous* (enumerated in section IV) from one another. The other half of *Athous*, as represented by the *vittatus* and *rufifrons* groups, is closely allied to *Elathous* and *Lepturoides*. In fact, *Lepturoides* is not more distinct from these groups of *Athous* than these are from each other. *Elathous*, on the other hand, appears to fill the gap between *Limonium* and *Athous* (pars) and probably should be retained as a distinct genus. The rather fragmentary larval record suggests, therefore, that *Athous* be revised into two genera, as in sections III and IV and that *Hemicrepidius* might be included with the one part and *Lepturoides* with the other, or these retained as distinct genera as at present. *Elathous* should remain as a genus.

The writer is fully in accord with Van Dyke (1932, p. 356), who states that *Elathous bicolor* (LeConte) should not be included with the genus *Leptoschema* Horn. On the basis of larval characters *Leptoschema* belongs in the subfamily Elaterinae.

THE GENUS LIMONIUS

Limonium is less complex than *Ludius* and *Athous*. This is shown on page 191, the genus being confined to section III. However, the larvae exhibit considerable polymorphism, mainly in characters of the mandibles, nasale, and urogomphi. At present, it would appear premature to erect genera on these characters. However, if any revision of the genus were to be made on the basis of larval characters the following subdivisions are suggested:

SUBDIVISION 1: the *acneoniger* group; these larvae are well characterized by the mandibles, nasale, subnasale, and small outer urogomphal prongs.

SUBDIVISION 2: *L. pilosus* (Leske) and its allies; the single-pointed nasale, the subnasale, and the mandibles isolate this larval type.

SUBDIVISION 3: includes all remaining species of *Limonium* known in the larval stage. This subdivision brings together rather diverse forms, but the chief difference is that *pectoralis*, *aeger*, and *confusus* (?) all have very small outer prongs whereas the members of the *canus* group have well-developed outer prongs. However, this character does not appear to have high ordinal value, especially since *aeger* is obviously related to the *canus* group through several other characters.

THE GENERA HYPNOIDUS AND CRYPTOHYPNUS

There has been a tendency in recent years for taxonomists to suppress the genus *Cryptohypnus* and to place its species under

Hypnoidus. According to Hyslop (1921), *Elater riparius* Fabricius was designated by Westwood in 1840 as the type of *Hypnoidus* Stephens; in 1859 the same species was designated by Thompson as the type of *Cryptohypnus*. If *riparius* be used as the type of *Hypnoidus*, then species such as *H. dubius* (Horn), *H. musculus* (Eschscholtz) and *H. maritimus* Curtis must be placed in a distinct genus. On the basis of larval characters, *riparius* and its allies definitely are not congeneric with *H. dubius* and its allies.¹⁶ The latter group have simple urogomphi, a 1-segmented galea, a very characteristic mandible, the prosternum undivided, and several other characters which separate them widely from the species which commonly have been placed in *Cryptohypnus*.

THE TRIBE LEPTUROIDINI

Without a careful study of the larvae of other tribes of the Pyrochorinae, the writer cannot appraise properly the status of the Lepturoidini. However, it would appear to be a reasonably well-characterized group. *Cryptohypnus* and *Melanactes*, which Leng (1920) placed in the tribes Hypnoidini and Melanactini, respectively, properly belong in the Lepturoidini. The most aberrant genera are *Eanus* and *Hypnoidus*. These are extreme forms and appear to be quite isolated within the tribe. It may be that larvae eventually will be found to link these genera more closely to the other Lepturoidini.

LIST OF SPECIES STUDIED

This list is designed to serve two main purposes: First, as an index to the principal descriptive sections on each species; and second, as a ready reference to the continental representation and the general reliability of the material used. The genera are listed alphabetically and the species alphabetically under each genus. The following symbols are used: Aus. for the continent of Australia; Eur. for Eurasia; N.A. for North America; * for species of which reared adults and their larval exuviae were available to the writer; # for species whose identification was known to be or believed to be based upon rearing, but reared adults could not be obtained for confirmation; x for species whose identification was believed to be fairly reliable, but not based upon rearing as far as was known; and o for species whose identification was very uncertain. Symbols in paren-

¹⁶ Support of this conclusion is given in a recent critical review based upon adult characters. (Vide M. C. Lane, "Some Generic Corrections in the Elateridae, II," Proc. Ent. Soc. Washington, vol. 50, No. 8, pp. 221-223, November 1948.)

theses indicate that larval material was not available to the writer and all knowledge of such species was obtained from the literature.

	Species	Distribution	Page
*	<i>Athous brightwelli</i> (Kirby)	N.A.	173
*	“ <i>cucullatus</i> (Say)	N.A.	175
#	“ <i>haemorrhoidalis</i> (Fabricius)	Eur.	171
x	“ <i>hirtus</i> (Herbst)	Eur.	180
#	“ <i>mutilatus</i> Rosenhauer	Eur.	174
*	“ <i>niger</i> (Linnaeus)	Eur.	180
*	“ <i>nigropilis</i> Motschulsky	N.A.	175
#	“ <i>pallidipennis</i> Mannerheim	N.A.	173
*	“ <i>rufifrons</i> (Randall)	N.A.	173
*	“ <i>scapularis</i> (Say)	N.A.	175
#	“ <i>subfuscus</i> (Müller)	Eur.	172
#	“ <i>undulatus</i> (DeGeer)	Eur. & N.A.	177
#	“ <i>villosus</i> (Geoffroy)	Eur.	177
#	“ <i>vittatus</i> (Fabricius)	Eur.	172
#	<i>Crepidomenus queenslandicus</i> Blair	Aus.	181
*	<i>Cryptohypnus abbreviatus</i> (Say)	N.A.	185
*	“ <i>sanborni</i> Horn	N.A.	184
#	“ <i>funeris</i> Candeze	N.A.	185
*	“ <i>nocturnus</i> (Eschscholtz)	N.A.	184
#	“ <i>riparius</i> (Fabricius)	Eur.	184
x	<i>Eanus costalis</i> (Paykull)	Eur.	188
*	“ <i>decoratus</i> (Mannerheim)	N.A.	187
*	<i>Elathous bicolor</i> LeConte	N.A.	167
*	<i>Hemicrepidius bilobatus</i> (Say)	N.A.	180
#	“ <i>carbonatus</i> (LeConte)	N.A.	180
*	“ sp., near <i>carbonatus</i> (LeConte)	N.A.	180
*	“ <i>hemipodus</i> (Say)	N.A.	180
*	“ <i>memnonius</i> (Herbst)	N.A.	180
*	<i>Hypnoidus dubius</i> (Horn)	N.A.	187
x	“ <i>maritimus</i> Curtis	Eur.	187
*	“ <i>musculus</i> (Eschscholtz)	N.A.	187
*	<i>Lepturoides denticornis</i> (Kirby)	N.A.	169
o	“ <i>fulvus</i> (Motschulsky)	N.A.	169
#	“ <i>linearis</i> (Linnaeus)	Eur.	169
*	<i>Limonium aeger</i> LeConte	N.A.	163
#	“ <i>acneoniger</i> (DeGeer)	Eur.	159
o	“ <i>anceps</i> LeConte	N.A.	164
#	“ <i>californicus</i> (Mannerheim)	N.A.	164
#	“ <i>canus</i> LeConte	N.A.	164
o	“ <i>confusus</i> LeConte	N.A.	162
#	“ <i>consimilis</i> Walker	N.A.	159
#	“ <i>dubitans</i> LeConte	N.A.	164
x	“ <i>ectypus</i> (Say)	N.A.	164
*	“ sp., near <i>ectypus</i> (Say)	N.A.	164
o	“ <i>occidentalis</i> Candeze	N.A.	164
*	“ <i>pectoralis</i> LeConte	N.A.	161
x	“ <i>pilosus</i> (Leske)	Eur.	160
#	“ <i>subauratus</i> LeConte	N.A.	164

	Species	Distribution	Page
#	<i>Ludius aeneus</i> (Linnaeus)	Eur.	46
*	" <i>acripennis acripennis</i> (Kirby)	N.A.	42
*	" <i>acripennis destructor</i> Brown	N.A.	19
(#)	" <i>affinis</i> (Paykull)	Eur.	93
(x)	" <i>amplicollis</i> (Germar)	Eur.	64
*	" <i>appressus</i> (Randall)	N.A.	135
x	" <i>appropinquans</i> (Randall)	N.A.	44
#	" <i>bipustulatus</i> (Linnaeus)	Eur.	106
#	" <i>bombycinus</i> (Germar)	N.A.	91
*	" <i>castaneus</i> (Linnaeus)	Eur.	89
*	" <i>cinctus</i> (Paykull)	Eur.	104
o	" <i>cruciatus festivus</i> (LeConte)	N.A.	62
*	" <i>cupreus</i> (Fabricius)	Eur.	126
#	" <i>cupreus aeruginosus</i> (Fabricius)	Eur.	127
x	" <i>cylindriciformis</i> (Herbst)	N.A.	156
*	" <i>divaricatus</i> (LeConte)	N.A.	118
*	" <i>glaucus</i> (Germar)	N.A.	50
*	" <i>hieroglyphicus</i> (Say)	N.A.	73
o	" <i>inflatus</i> (Say)	N.A.	55
*	" <i>kendalli</i> (Kirby)	N.A.	134
x	" <i>latus</i> (Fabricius)	Eur.	48
x	" <i>limoniiformis</i> (Horn)	N.A.	151
*	" <i>medianus</i> (Germar)	N.A.	92
(x)	" <i>melancholicus</i> (Fabricius)	Eur.	64
#	" <i>nebraskensis</i> (Bland)	N.A.	81
o	" <i>nigricornis</i> (Panzer)	Eur.	118
*	" <i>nitidulus</i> (LeConte)	N.A.	112
#	" <i>pectinicornis</i> (Linnaeus)	Eur.	131
*	" <i>propola propola</i> (LeConte)	N.A.	68
*	" <i>protractus</i> (LeConte)	N.A.	143
*	" <i>pruininus</i> (Horn)	N.A.	45
#	" <i>pudicus</i> Brown	N.A.	74
(#)	" <i>purpureus</i> (Poda)	Eur.	93
#	" <i>pyrrhos</i> (Herbst)	N.A.	142
*	" <i>resplendens acrvarius</i> (Randall)	N.A.	136
#	" <i>rotundicollis</i> (Say) ("Eastern Species")	N.A.	96
#	" <i>rotundicollis</i> (Say) ("Western Species")	N.A.	97
o	" <i>rufopleuralis</i> Fall	N.A.	117
#	" <i>semivittatus</i> (Say)	N.A.	66
x	" <i>sexualis</i> Brown	N.A.	57
#	" <i>sjaelandicus</i> (Müller)	Eur. & N.A.	142
(x)	" <i>spretus</i> (Mannerheim)	Eur.	63
#	" <i>sulcicollis</i> (Say)	N.A.	102
x	" <i>tessellatus</i> (Linnaeus)	Eur.	84
*	" <i>trivulvatus</i> (Randall)	N.A.	76
x	" <i>viduus</i> Brown	N.A.	90
(#)	" <i>virrens</i> (Schrank)	Eur.	133
#	<i>Melanactes densus</i> LeConte	N.A.	189

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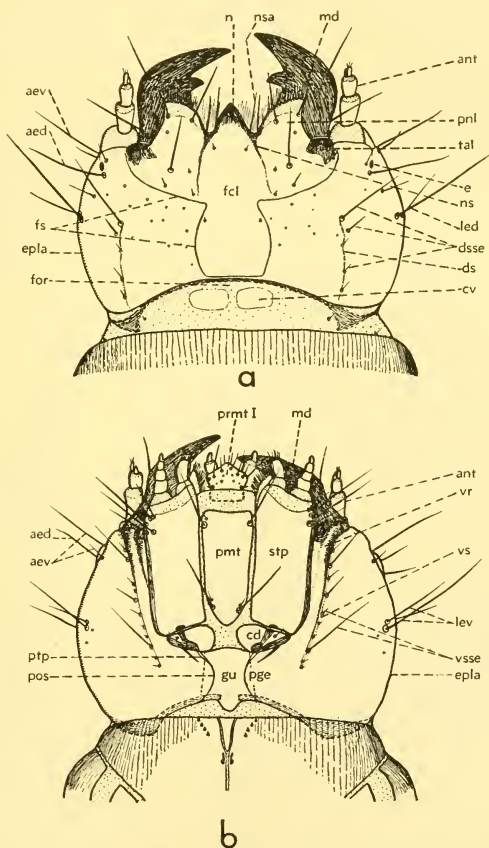


FIG. 1.—*Ludius aeripennis destructor* Brown.
a, head, dorsal view; *b*, head, ventral view.

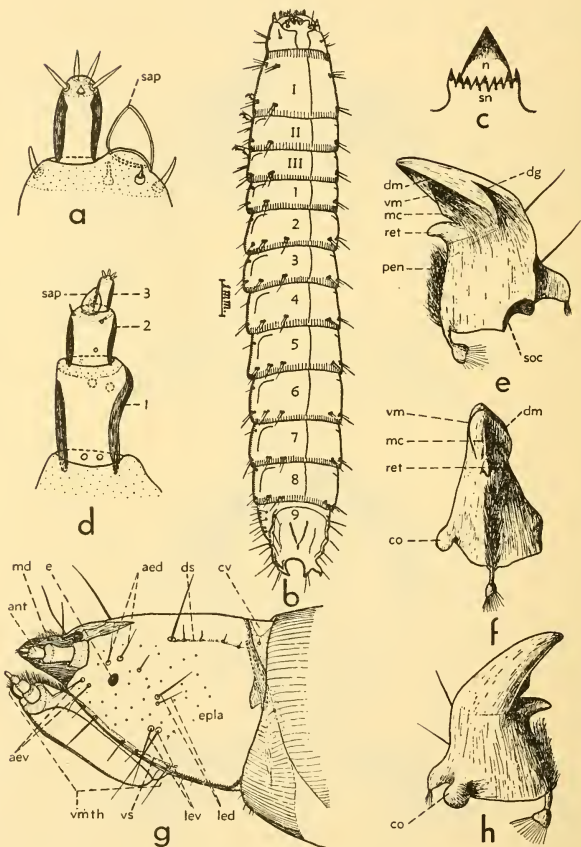


FIG. 2.—*Ludius aeripennis destructor* Brown.

a, third segment and tip of second segment of left antenna, mediiodorsal view; *b*, whole larva, dorsal view; *c*, nasale and subnasale, ventral view; *d*, left antenna, ventral view; *e*, right mandible, dorsal view; *f*, right mandible, medial view; *g*, head, lateral view; *h*, right mandible, ventral view.

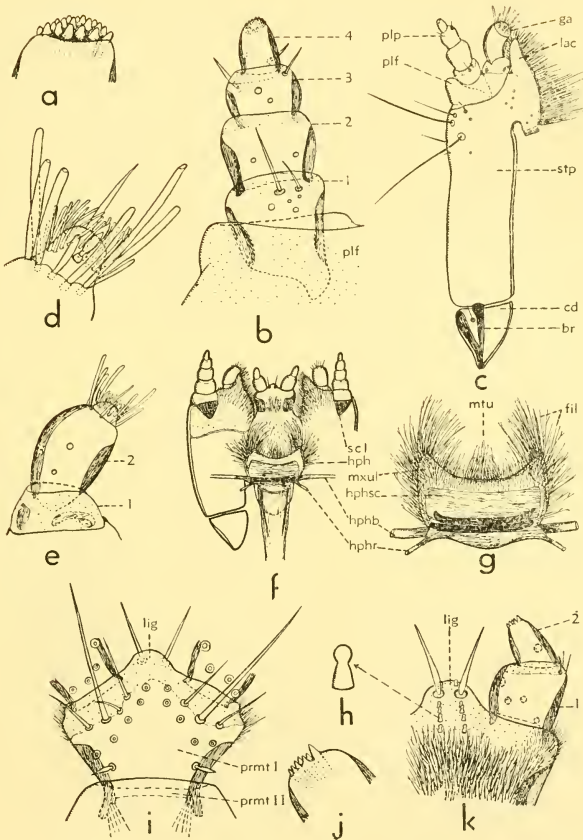


FIG. 3.—*Ludius aeripennis destructor* Brown.

a, tip of maxillary palpus, dorsal view (oil immersion); *b*, maxillary palpus, medioventral view; *c*, right maxilla, medioventral view; *d*, tip of galea, dorsal view (oil immersion); *e*, right galea, medioventral view; *f*, preoral cavity with hypopharynx in situ, dorsal view; *g*, posterior portion of hypopharynx, dorsal view; *h*, "sensory" peg from dorsal surface of ligula; *i*, first prementum and second prementum, ventral view; *j*, tip of labial palpus, dorsal view (oil immersion); *k*, first prementum, dorsal view.

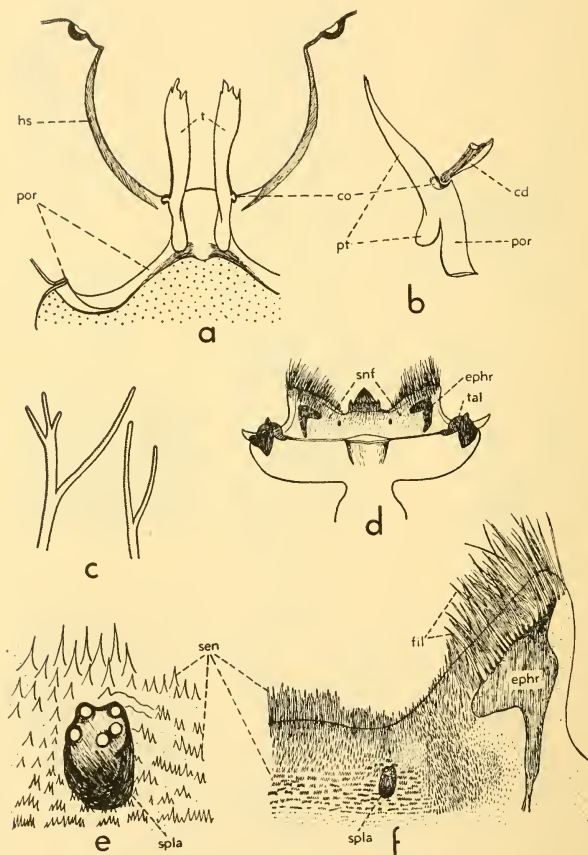


FIG. 4.—*Ludius acripennis destructor* Brown.

a, tentorium, in situ, dorsal view (semidiagrammatic); b, right half of tentorium, lateral view (semidiagrammatic); c, branching filaments from hypopharynx; d, dorsal aspect of preoral cavity; e, "sensory" plate and surrounding sensilla on subnasal flap (oil immersion); f, left half of "subnasal flap."

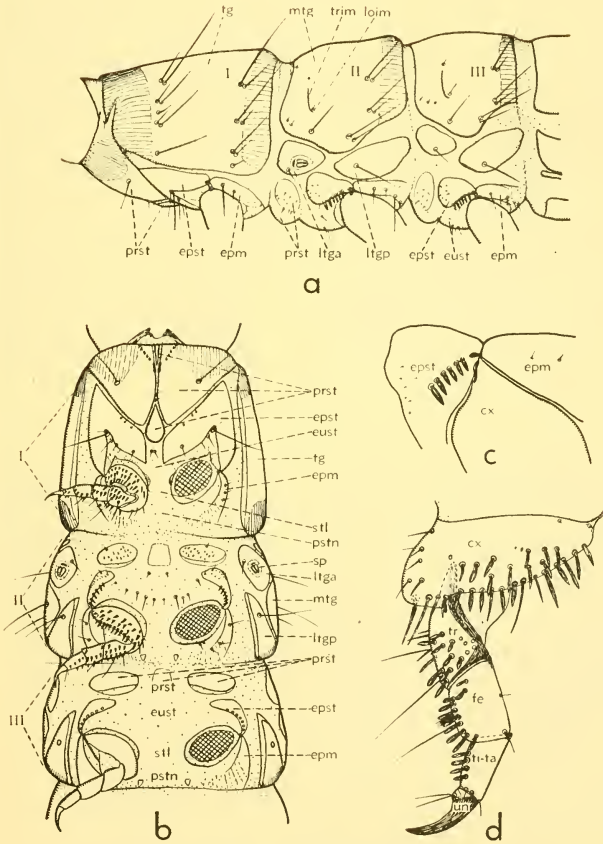


FIG. 5.—*Ludius acripennis destructor* Brown.

a, thorax, lateral view; b, thorax, ventral view (left legs removed; setae omitted from metathorax); c, episternum of mesothorax, lateral view, to show spinelike setae; d, left leg of mesothorax, anterior aspect.

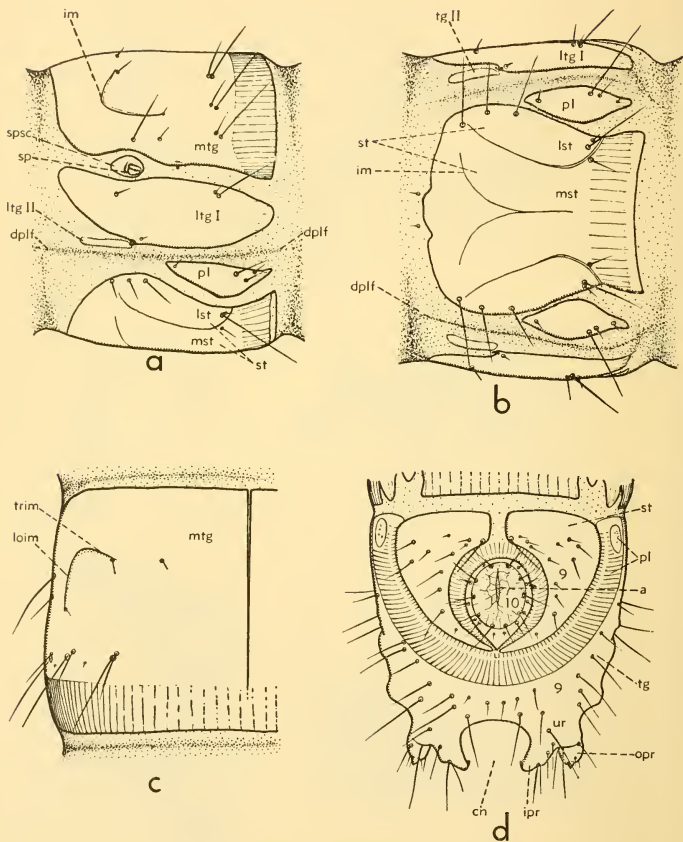


FIG. 6.—*Ludius aeripennis destructor* Brown.

a, fourth abdominal segment, lateral view; *b*, fourth abdominal segment, ventral view; *c*, mediotergite of fourth abdominal segment, dorsal view; *d*, ninth and tenth abdominal segments, ventral view.

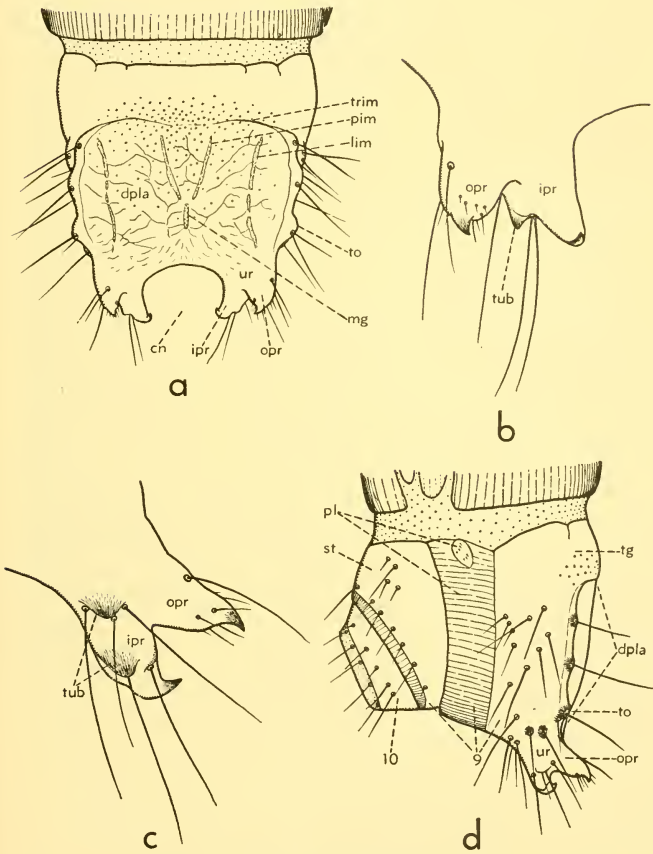


FIG. 7.—*Ludius aeripennis destructor* Brown.

a, ninth abdominal segment, dorsal view; b, left urogomphus, dorsal view; c, left urogomphus, lateral view; d, ninth and tenth abdominal segments, lateral view.

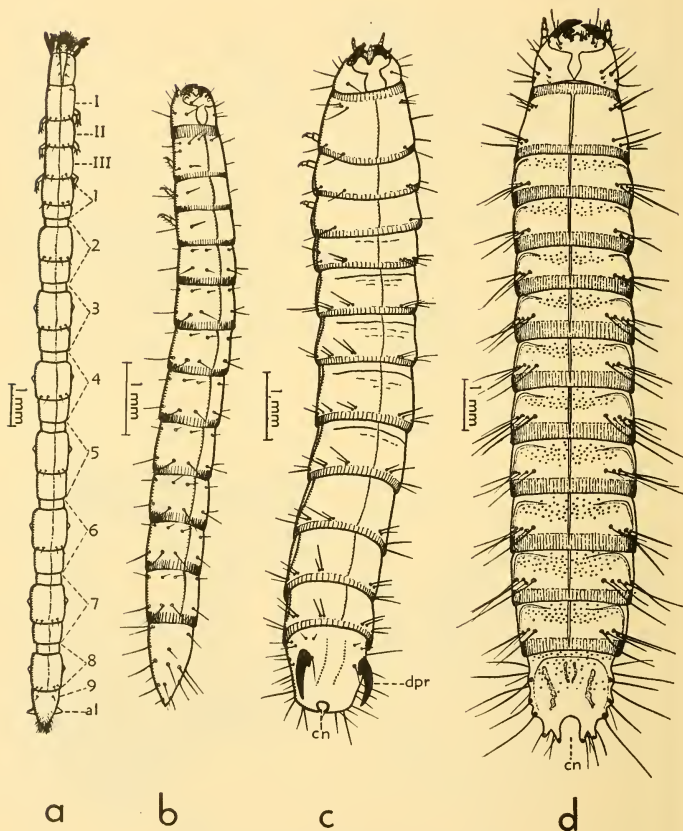


FIG. 8.—Representatives of subfamilies.

a, *Cardiophorus* sp., larva, dorsal view; subfamily Cardiophorinae. *b*, *Dalopius parvulus* Brown, larva, dorsal view; subfamily Elaterinae. *c*, *Oestodes tenuicollis* (Randall), larva, dorsal view; subfamily Oestodinae. *d*, *Ludius tessellatus* (Linnaeus), larva, dorsal view; subfamily Pyrophorinae.

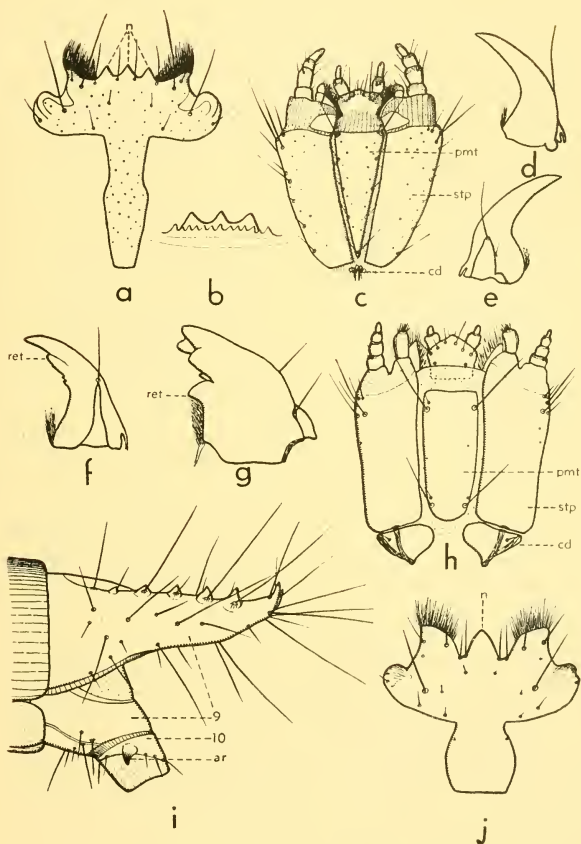


FIG. 9.—*Aeolus*, *Hypnoidus*, *Limonius*, and *Ludius*.

a-e, i, *Aeolus mellillus marginicollis* (Horn): *a*, frontoclypeal region, dorsal view; *b*, nasale and subnasale, ventral view; *c*, ventral mouthparts, ventral view; *d*, left mandible, ventral view; *e*, right mandible, dorsal view; *i*, ninth and tenth abdominal segments, lateral view. *f*, *Hypnoidus dubius* (Horn): right mandible, dorsal view. *g*, *Limonius acneoniger* (DeGeer): right mandible, dorsal view. *h, j*, *Ludius aeripennis destructor* Brown: *h*, ventral mouthparts, ventral view; *j*, frontoclypeal region, dorsal view.

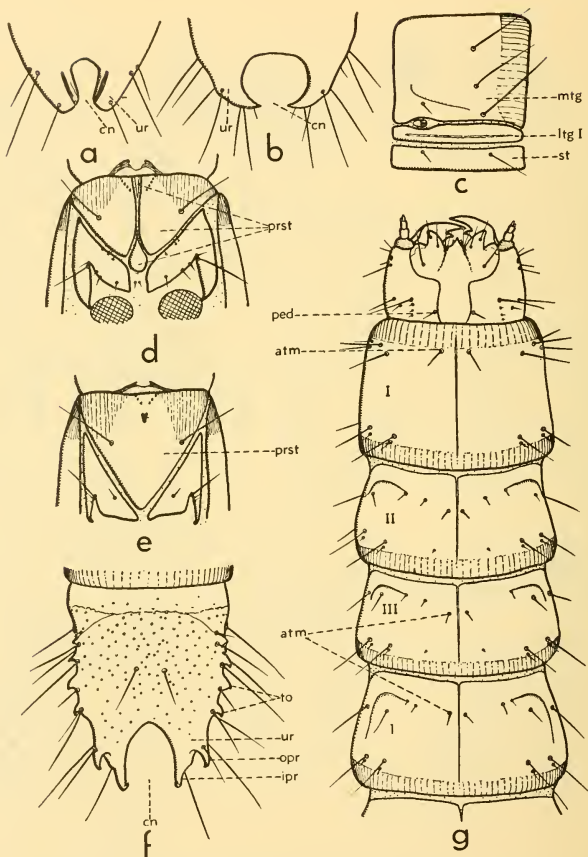
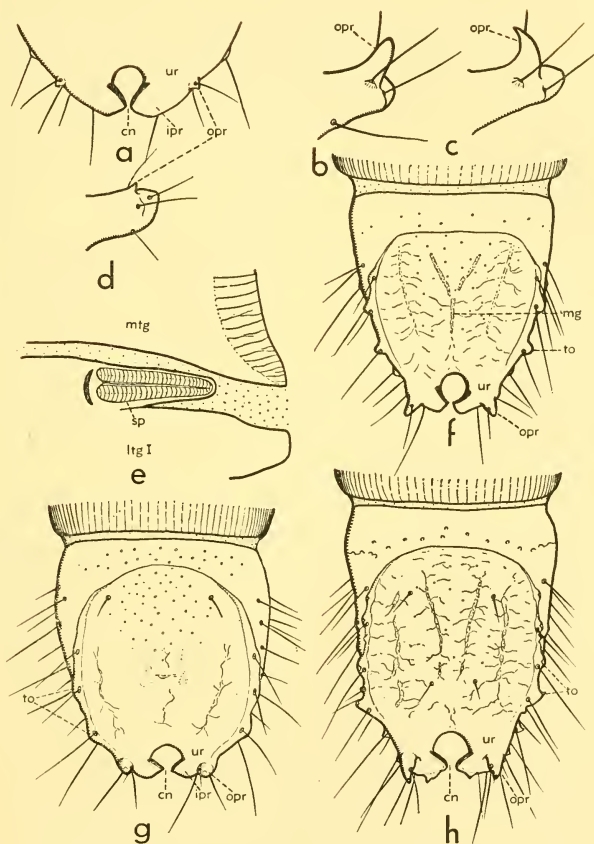


FIG. 10.—*Eanus decoratus*, *Ludius*, *Limonius*, *Crepidomenus* and *Cryptohypnus*.

a, c, *Eanus decoratus* (Mannerheim): *a*, urogomphi, dorsal view; *c*, third abdominal segment, lateral view. *b*, *Hypnoidus dubius* (Horn): urogomphi, dorsal view. *d*, *Ludius aeripennis destructor* Brown: presternal area of prothorax, ventral view. *e*, *Limonius dubitans* LeConte: presternal area of prothorax, ventral view. *f*, *Crepidomenus queenslandicus* Blair: ninth abdominal segment, dorsal view. *g*, *Cryptohypnus nocturnus* (Eschscholtz): head, thorax, and first abdominal segment, dorsal view.

FIG. 11.—*Limonius*, *Ludius*, and *Elathous*.

a, *Limonius aeneoniger* (DeGeer): urogomphi, dorsal view. *b*, *f*, *Ludius resplendens aerarius* (Randall): *b*, left urogomphus, lateral view; *f*, ninth abdominal segment, dorsal view. *c*, *Elathous bicolor* (LeConte): left urogomphus, lateral view. *d*, *Limonius aeger* LeConte: left urogomphus, lateral view. *e*, *Ludius pyrrhos* (Herbst): spiracle of eighth abdominal segment. *g*, *Limonius ectypus* Say (?): ninth abdominal segment, dorsal view. *h*, *Ludius limoniiformis* (Horn) (?): ninth abdominal segment, dorsal view.

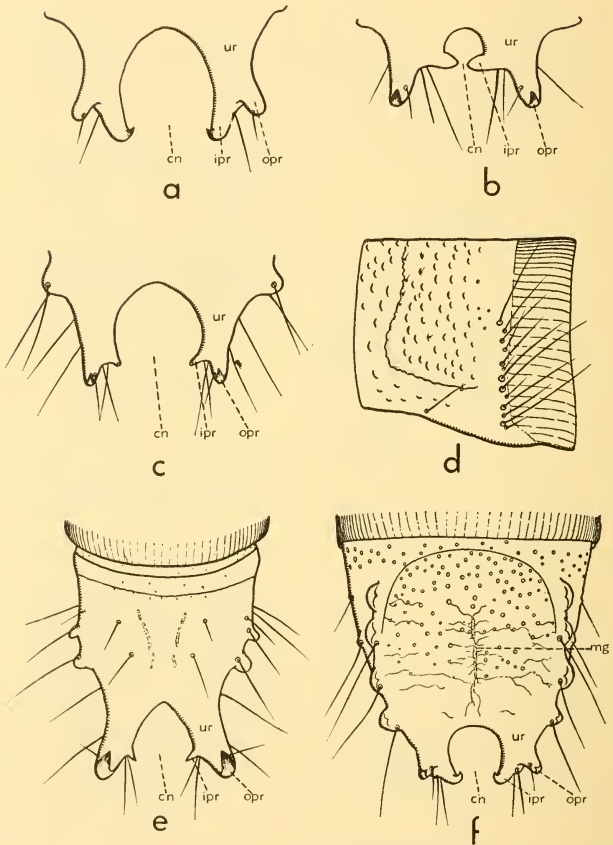


FIG. 12.—*Athous*, *Lepturooides*, *Hemicrepidius*, and *Ludius*.

a, *Athous cucullatus* (Say), urogomphi, dorsal view. *b*, *Lepturooides linearis* (Linnaeus), urogomphi, dorsal view. *c*, *Athous mutilatus* Rosenhauer, urogomphi, dorsal view. *d*, *Hemicrepidius* sp., mediotergite of fourth abdominal segment, lateral view. *e*, *Ludius divaricatus* (LeConte), ninth abdominal segment, dorsal view. *f*, *Hemicrepidius memnonius* (Herbst), ninth abdominal segment, dorsal view (drawn from a larval exuvium).

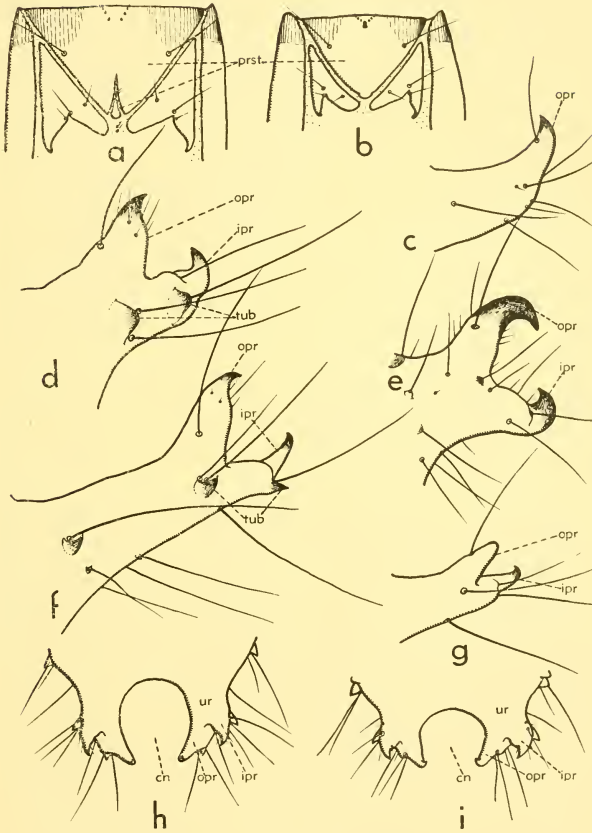
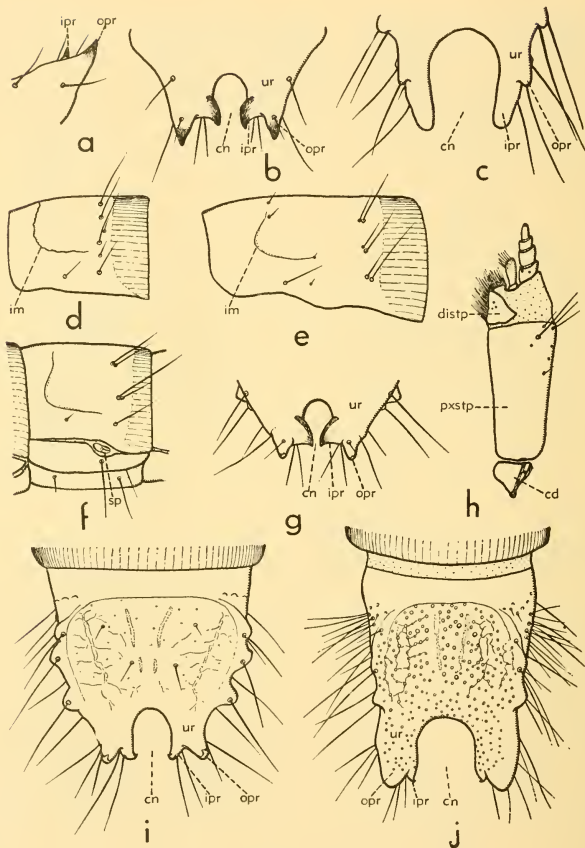


FIG. 13.—Species of *Ludius*.

a, *Ludius nitidulus* (LeConte): presternal area of prothorax, ventral view. b, *L. resplendens aerarius* (Randall): presternal area of prothorax, ventral view. c, *L. propola propola* (LeConte): left urogomphus, lateral view. d, *L. acripennis destructor* Brown: left urogomphus, lateral view. e, *L. sexualis* Brown (?): left urogomphus, lateral view. f, h, *L. glaucus* (Germar): f, left urogomphus, lateral view; h, urogomphi, dorsal view. g, *L. triundulatus* (Randall): left urogomphus, lateral view. i, *L. pruininus* (Horn): urogomphi, dorsal view.

FIG. 14.—Species of *Ludius*.

a, b, Ludius appressus (Randall): *a*, left urogomphus, lateral view; *b*, urogomphi, dorsal view. *c, L. bipustulatus* (Linnaeus): urogomphi, dorsal view. *d, L. triundulatus* (Randall): mediotergite of fifth abdominal segment, lateral view. *e, L. aeripennis destructor* Brown: mediotergite of fourth abdominal segment, lateral view. *f, L. sjaelandicus* (Müller): eighth abdominal segment, lateral view. *g, L. kendalli* (Kirby): urogomphi, dorsal view. *h, L. cinctus* (Paykull): left maxilla, ventral view. *i, L. nitidulus* (LeConte): ninth abdominal segment, dorsal view. *j, L. rotundicollis* (Say) ("Western species"), ninth abdominal segment, dorsal view.

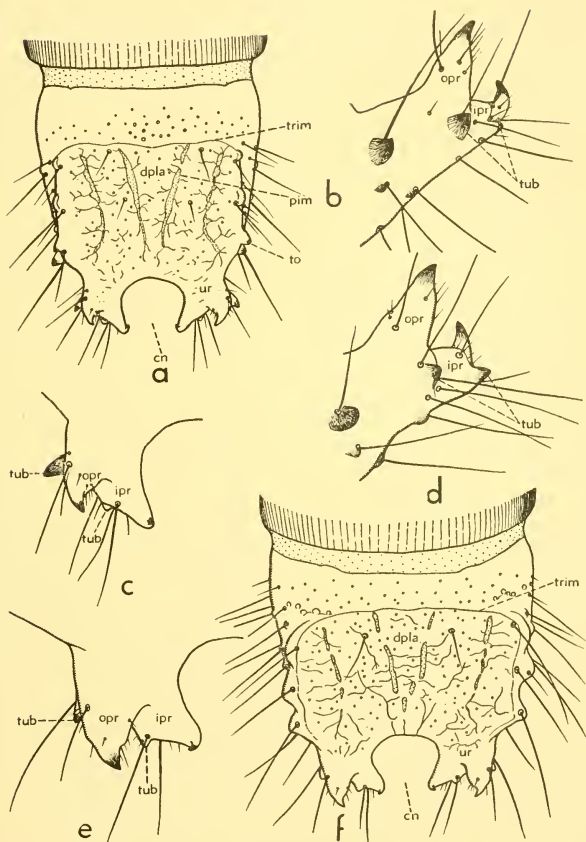
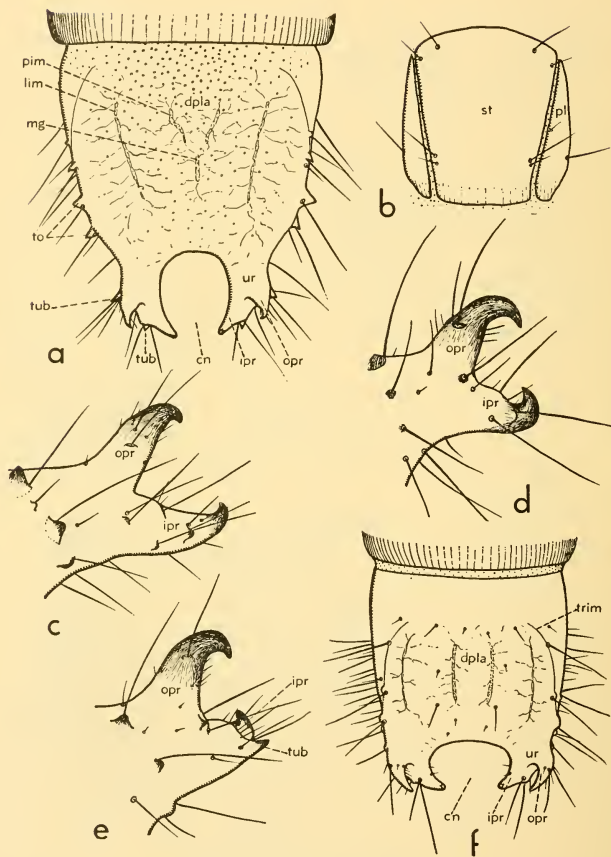
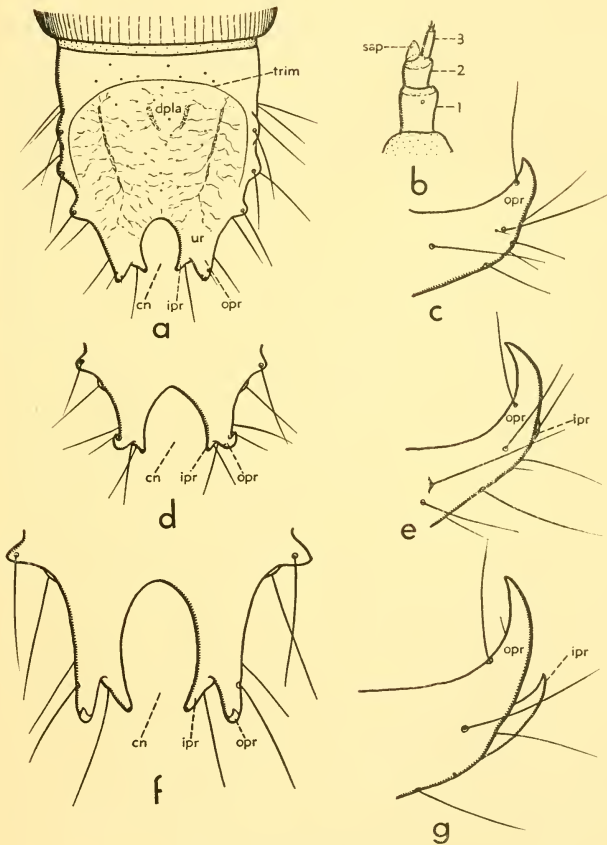


FIG. 15.—*Ludius aeripennis* group.

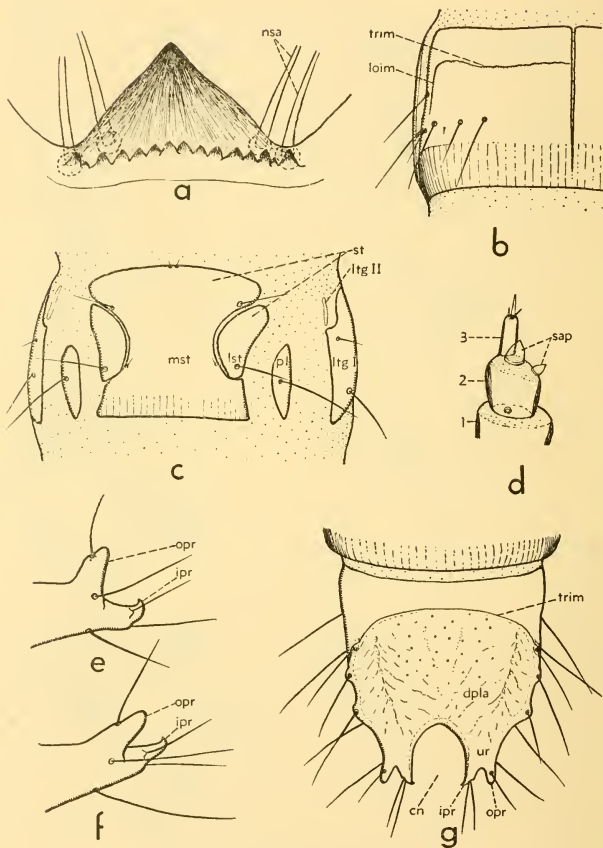
a-c, *Ludius pruininus* (Horn): *a*, ninth abdominal segment, dorsal view; *b*, left urogomphus, lateral view; *c*, left urogomphus, dorsal view. *d-f*, *L. latus* (Fabricius): *d*, left urogomphus, lateral view; *e*, left urogomphus, dorsal view; *f*, ninth abdominal segment, dorsal view.

FIG. 16.—Species of *Ludius*.

a, *Ludius glaucus* (Germar): ninth abdominal segment, dorsal view. *b*, *e*, *L. semivittatus* (Say) (?): *b*, first abdominal segment, ventral view (semi-diagrammatic, the larva being much shrunken); *e*, left urogomphus, lateral view. *c*, *L. cruciatus festivus* (LeConte) (?): left urogomphus, lateral view. *d*, *f*, *L. sexualis* Brown (?): *d*, left urogomphus, lateral view; *f*, ninth abdominal segment, dorsal view.

FIG. 17.—*Ludius propola* group.

a-c, *Ludius propola propola* (LeConte): *a*, ninth abdominal segment, dorsal view; *b*, right antenna, medial view; *c*, left urogomphus, lateral view. *d, e*, *L. pudicus* Brown: *d*, urogomphi, dorsal view; *e*, left urogomphus, lateral view. *f, g*, *L. hieroglyphicus* (Say): *f*, urogomphi, dorsal view; *g*, left urogomphus, lateral view.

FIG. 18.—*Ludius triundulatus* group.

a-d, f, g, *Ludius triundulatus* (Randall): a, nasale and subnasale, ventral view; b, mediotergite of fifth abdominal segment, dorsal view; c, fifth abdominal segment, ventral view; d, second and third segments of left antenna, ventral view; f, left urogomphus, lateral view; g, ninth abdominal segment, dorsal view. e, *L. nebraskensis* (Bland) (?): left urogomphus, lateral view.

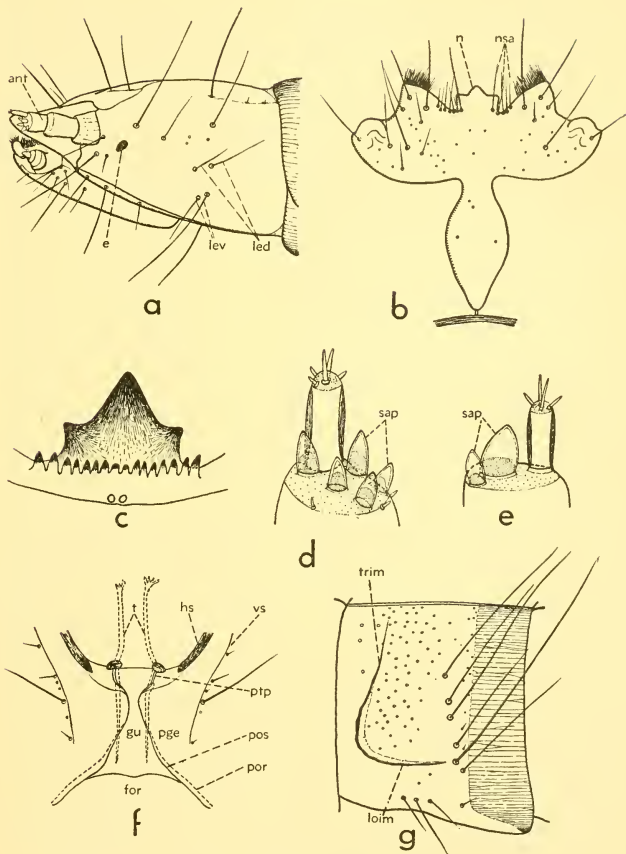


FIG. 19.—*Ludius fallax* group.

a, b, d, f, g, Ludius tessellatus (Linnaeus) : *a*, head, lateral view ; *b*, frontoclypeal region, dorsal view ; *d*, third segment and tip of second segment of left antenna, medioventral view ; *f*, gular area, showing position of tentorium, ventral view ; *g*, mediotergite of fourth abdominal segment, dorsolateral view. *c, e, L. castaneus* (Linnaeus) : *c*, nasale and subnasale, ventral view ; *e*, third segment and tip of second segment of left antenna, lateral view.

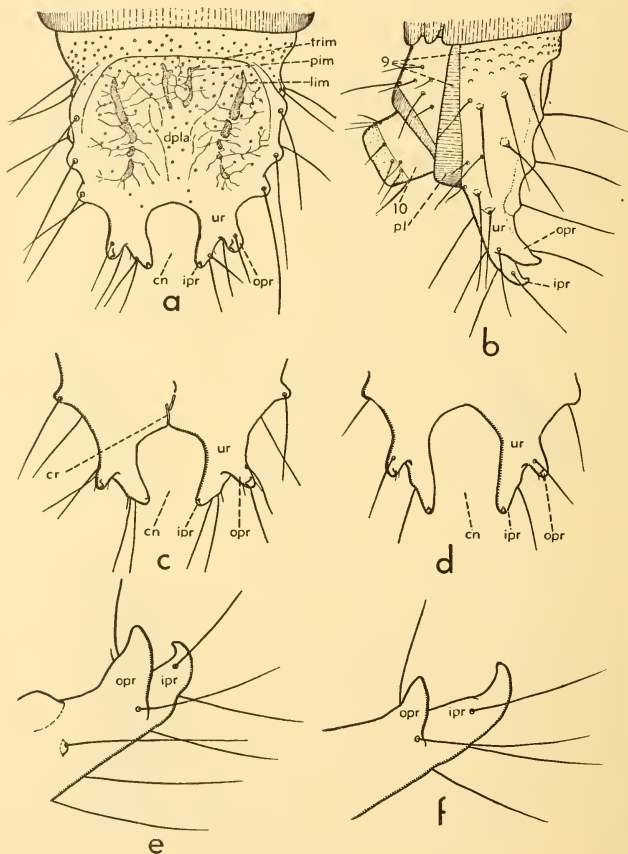
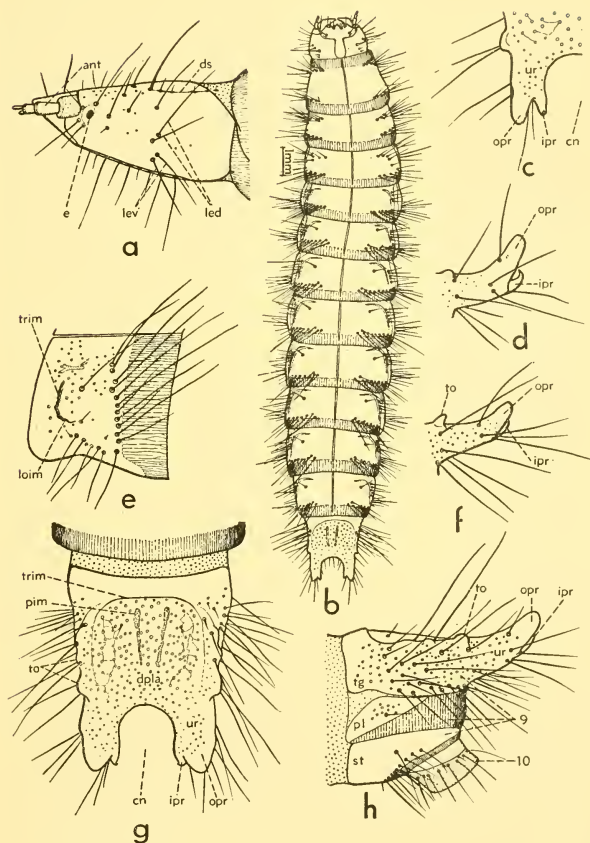


FIG. 20.—*Ludius fallax* group.

a, b, e, Ludius tessellatus (Linnaeus): *a*, ninth abdominal segment, dorsal view; *b*, ninth and tenth abdominal segments, lateral view; *e*, left urogomphus, lateral view. *c, L. castaneus* (Linnaeus): urogomphi, dorsal view. *d, f, L. bombycinus* (Germar): *d*, urogomphi, dorsal view (drawn from larval exuvium); *f*, left urogomphus, lateral view (drawn from larval exuvium).

FIG. 21.—*Ludius rotundicollis* group.

a, b, e, g, h, Ludius rotundicollis (Say) ("Western species"): *a*, head, lateral view (ventral mouthparts omitted); *b*, whole larva, dorsal view; *e*, mediotergite of fourth abdominal segment, dorsolateral view; *g*, ninth abdominal segment, dorsal view; *h*, ninth and tenth abdominal segments, lateral view. *c, d, L. sulcicollis* (Say): *c*, left urogomphus, dorsal view; *d*, left urogomphus, lateral view. *f, L. rotundicollis* (Say) ("Eastern species"): left urogomphus, lateral view.

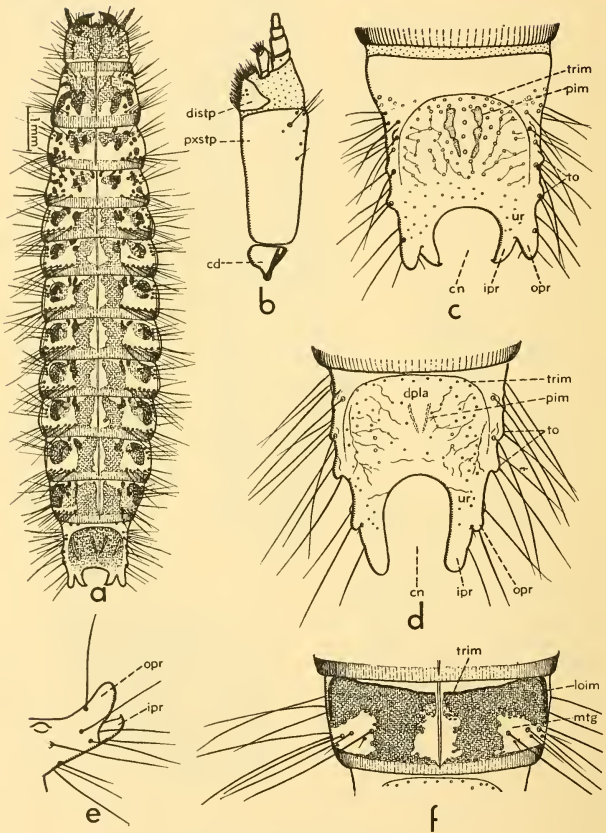


FIG. 22.—Species of *Ludius*.

a-c, e, Ludius cinctus (Paykull): *a*, whole larva, dorsal view (showing color pattern); *b*, left maxilla, ventral view; *c*, ninth abdominal segment, dorsal view (color pattern omitted); *e*, left urogomphus, lateral view. *d, f, L. bipustulatus* (Linnaeus): *d*, ninth abdominal segment, dorsal view (color pattern omitted); *f*, eighth abdominal segment, dorsal view (showing color pattern).

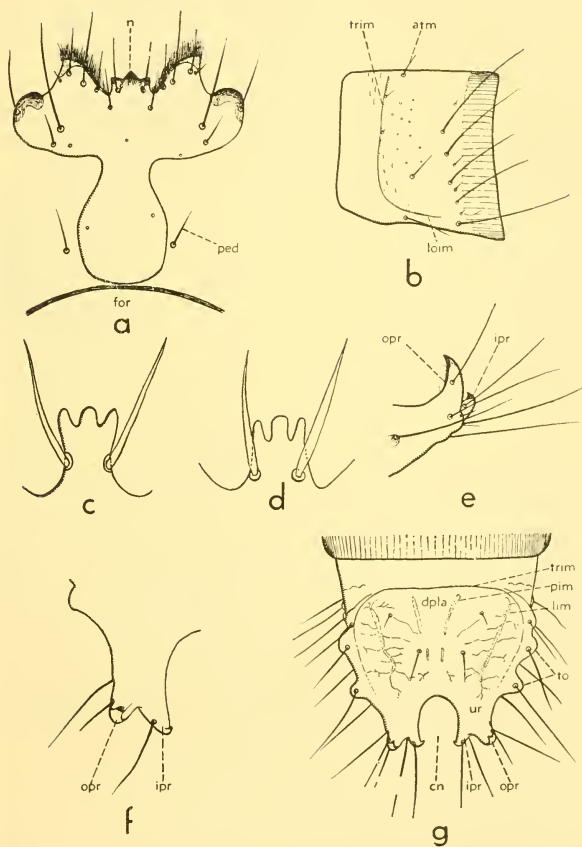


FIG. 23.—*Ludius nitidulus* group.

a, b, e, g, Ludius nitidulus (LeConte): *a*, frontoclypeal area, dorsal view; *b*, left mediotergite of seventh abdominal segment, dorsolateral view; *e*, left urogomphus, lateral view; *g*, ninth abdominal segment, dorsal view. *c, L. rufopleuralis* Fall (?): nasale, dorsal view. *d, f, L. nigricornis* (Panzer) (?): *d*, nasale, dorsal view; *f*, left urogomphus, dorsal view.

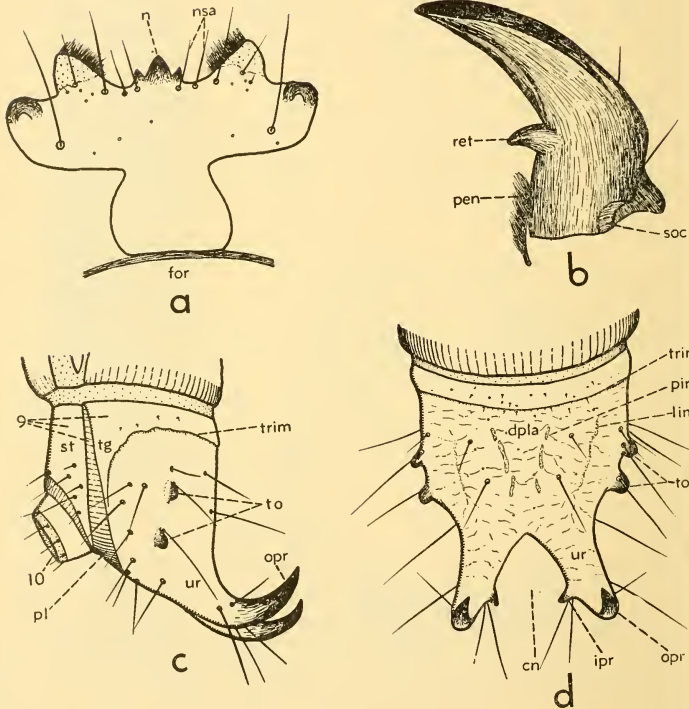
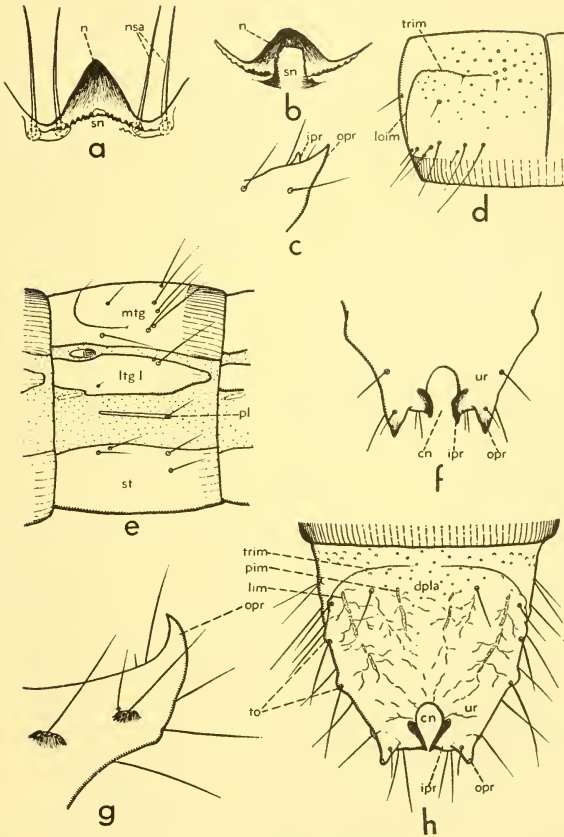


FIG. 24.—*Ludius divaricatus* (LeConte).

a, frontoclypeal area, dorsal view; *b*, right mandible, dorsal view; *c*, ninth and tenth abdominal segments, lateral view; *d*, ninth abdominal segment, dorsal view.

FIG. 25.—Species of *Ludius*.

a, *Ludius cupreus cupreus* (Fabricius): nasale and subnasale, ventral view. *b*, *c*, *f*, *L. appressus* (Randall) (drawn from larval exuvium): *b*, nasale and subnasale, ventral view; *c*, tip of left urogomphus, lateral view; *f*, urogomphi, dorsal view. *d*, *e*, *g*, *h*, *L. cupreus aeruginosus* (Fabricius): *d*, left mediotergite of eighth abdominal segment, laterodorsal view; *e*, fourth abdominal segment, ventrolateral view; *g*, left urogomphus, lateral view; *h*, ninth abdominal segment, dorsal view.

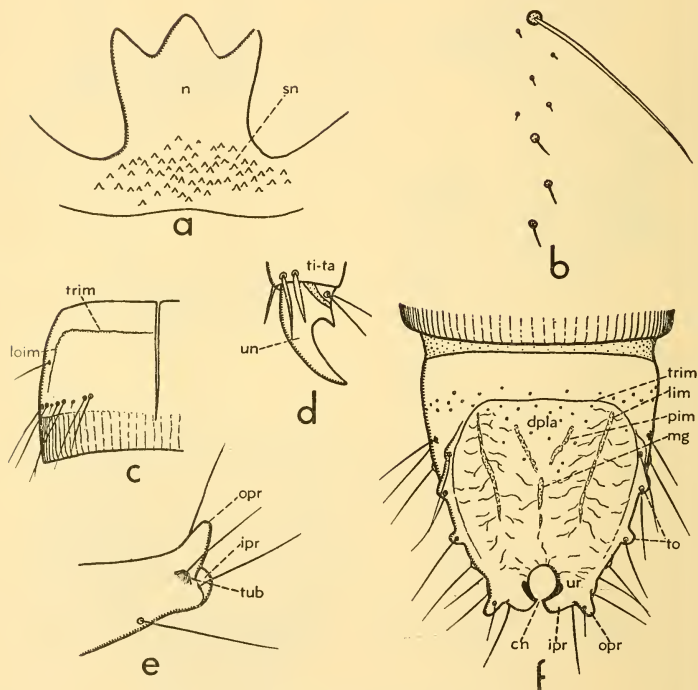


FIG. 26.—*Ludius resplendens acerarius* (Randall).

a, nasale and subnasale, ventral view; *b*, setal arrangement in left dorsal epicranial sulcus; *c*, left mediotergite of third abdominal segment, dorsal view; *d*, ungula of right prothoracic leg, anterior aspect; *e*, left urogomphus, lateral view; *f*, ninth abdominal segment, dorsal view.

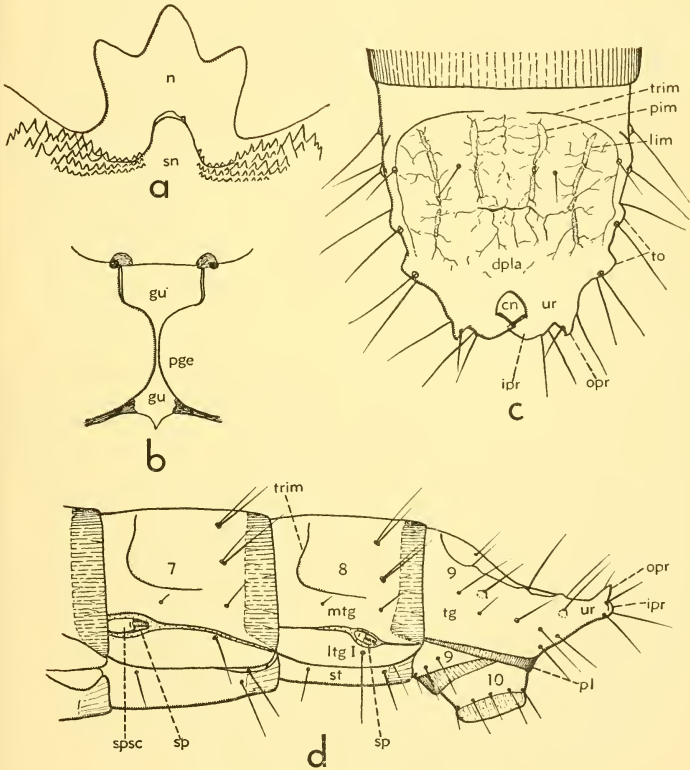


FIG. 27.—*Ludius sjaelandicus* (Müller).

a, nasale and subnasale, ventral view; b, gular area, ventral view; c, ninth abdominal segment, dorsal view; d, seventh, eighth, ninth, and tenth abdominal segments, lateral view.

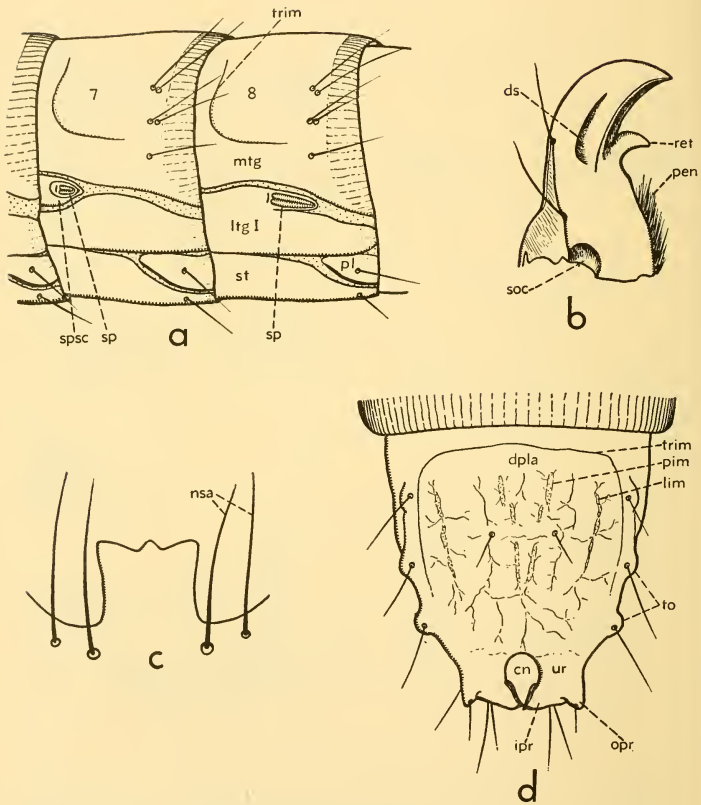
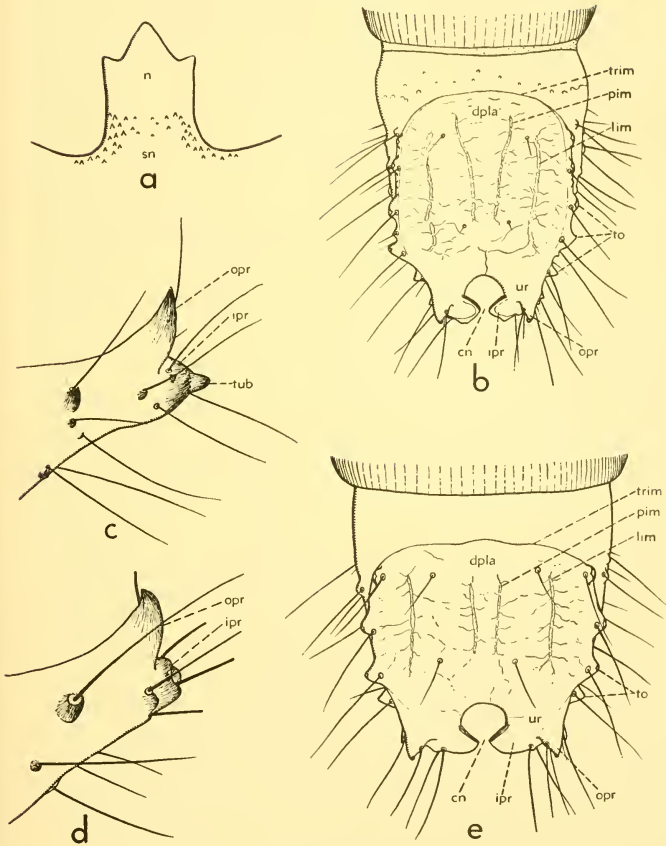
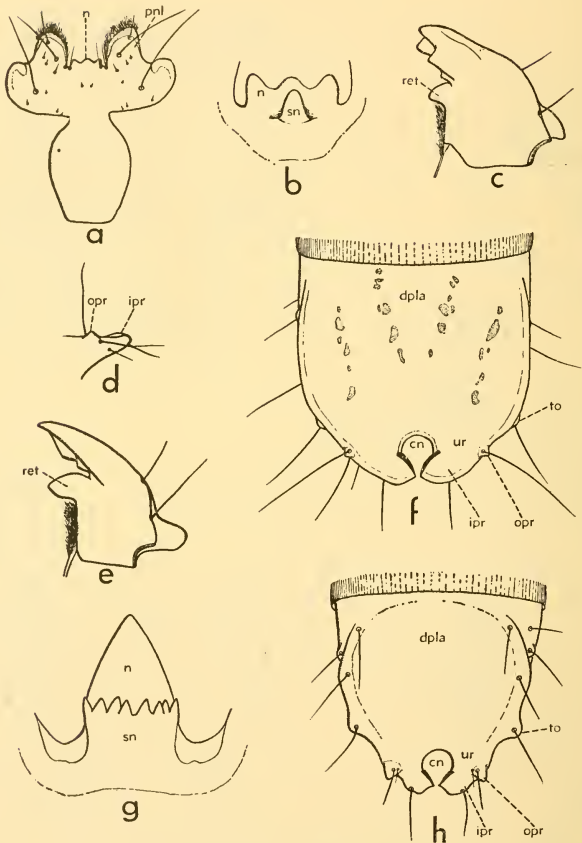


FIG. 28.—*Ludius pyrrhos* (Herbst).

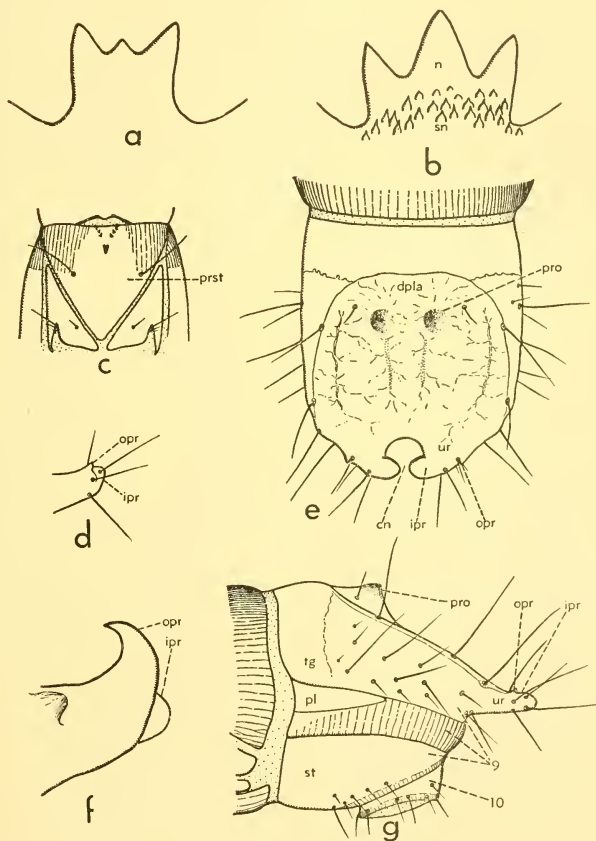
a, seventh and eighth abdominal segments, lateral view; *b*, left mandible, dorsal view; *c*, nasale, dorsal view; *d*, ninth abdominal segment, dorsal view.

FIG. 29.—*Ludius limoniiformis* group.

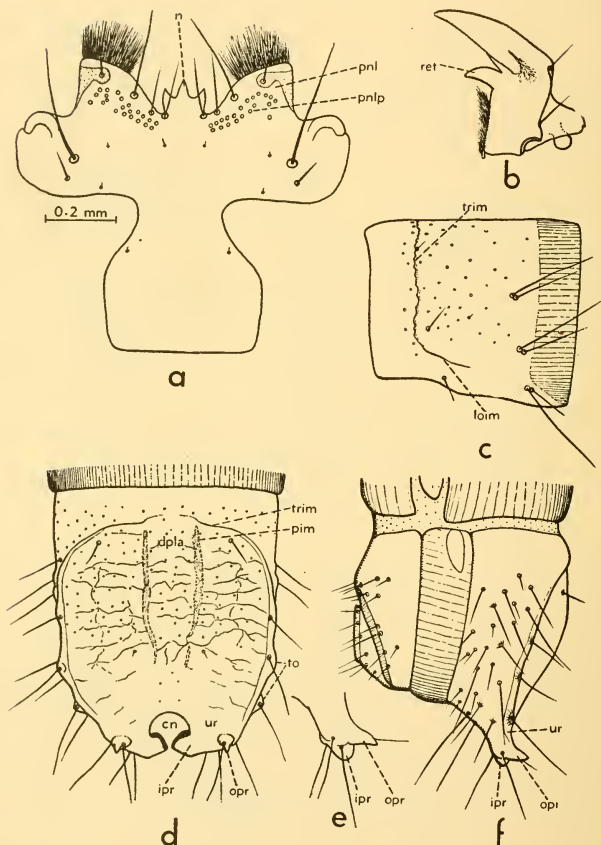
a-c, *Ludius limoniiformis* (Horn) (?): *a*, nasale and subnasale, ventral view; *b*, ninth abdominal segment, dorsal view; *c*, left urogomphus, lateral view. *d-e*, *L. cylindriciformis* (Herbst) (?): *d*, left urogomphus, lateral view; *e*, ninth abdominal segment, dorsal view.

FIG. 30.—Species of *Limonius*.

a-d, f, Limonius aeneoniger (DeGeer) (= *Pheletes bructeri* Panzer): *a*, frontoclypeal area, dorsal view; *b*, nasale and subnasale, ventral view; *c*, right mandible, dorsal view (probably somewhat eroded); *d*, left urogomphus, lateral view; *f*, ninth abdominal segment, dorsal view. *e, g, h, L. pilosus* (Leske) (?): *e*, right mandible, dorsal view; *g*, nasale and subnasale, ventral view; *h*, ninth abdominal segment, dorsal view.

FIG. 31.—Species of *Limonius*.

a, e, g, Limonius pectoralis LeConte: *a*, nasale, dorsal view; *e*, ninth abdominal segment, dorsal view; *g*, ninth and tenth abdominal segments, lateral view. *b, c, L. dubitans* LeConte (= *Nothodes dubitans*): *b*, nasale and subnasale, ventral view; *c*, presternal area of prothorax, ventral view. *d, L. aeger* LeConte: left urogomphus, lateral view. *f, L. subauratus* LeConte (?): left urogomphus, lateral view.

FIG. 32.—*Limonius canus* group.

a-e, *Limonius dubitans* LeConte (= *Nothodes dubitans*): *a*, frontoclypeal area, dorsal view; *b*, right mandible, lateral view; *c*, left mediotergite of fourth abdominal segment, lateral view; *d*, ninth abdominal segment, dorsal view; *e*, left urogomphus, lateral view. *f*, *L. ectypus* (Say) (?): ninth and tenth abdominal segments, lateral view.

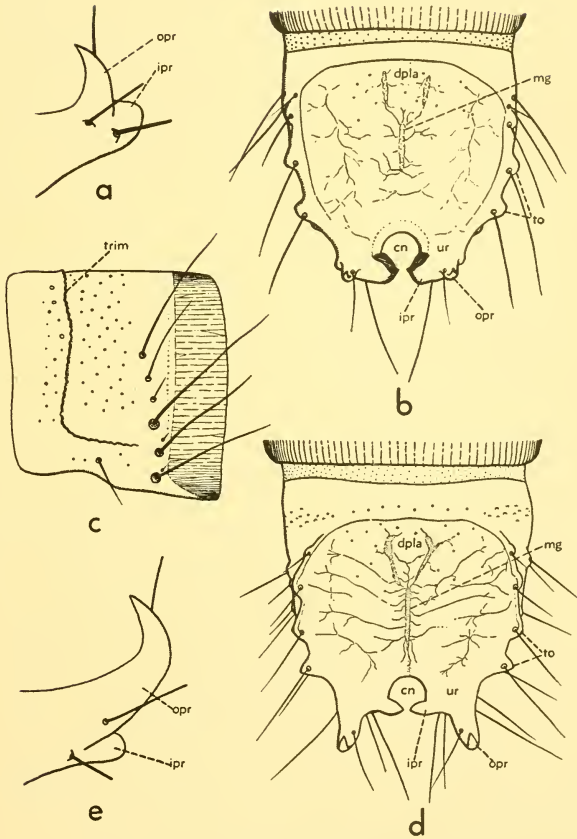
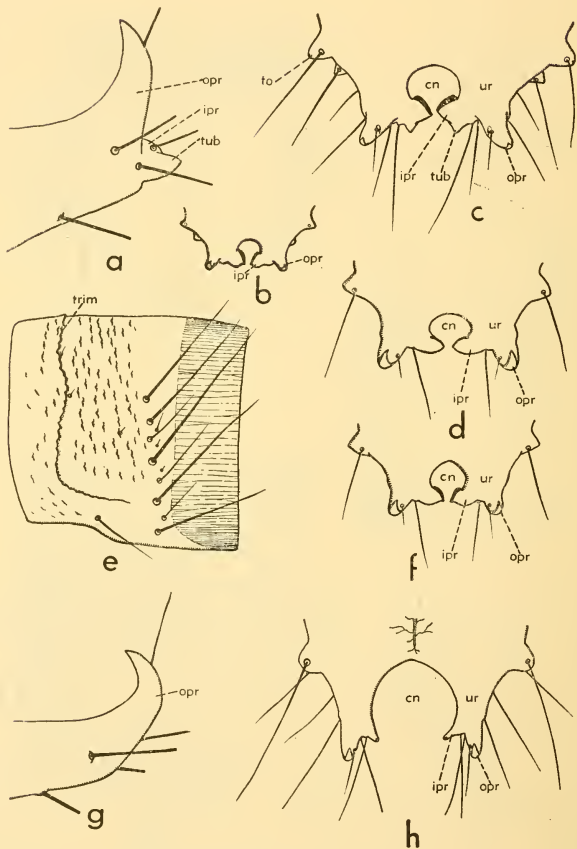
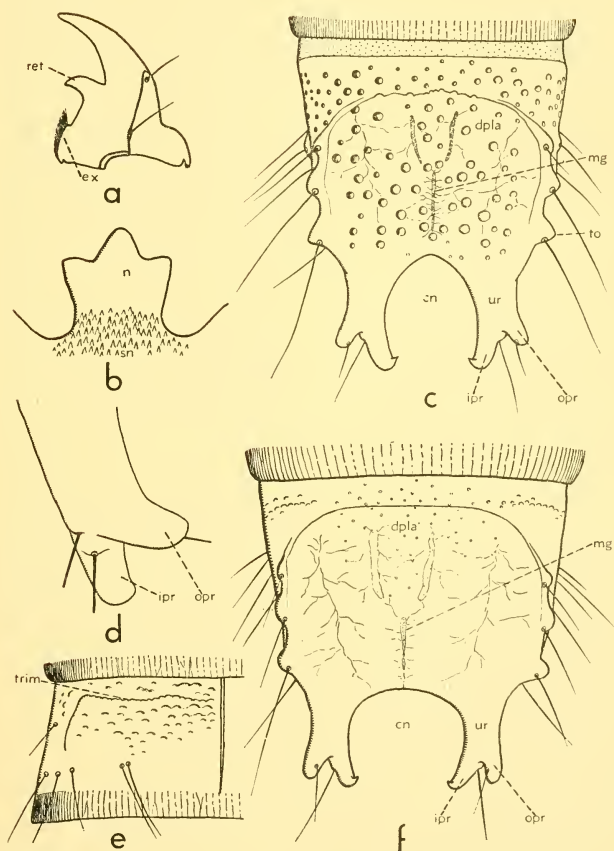


FIG. 33.—*Elathous bicolor* and *Lepturoides linearis*.

a, b, Elathous bicolor (LeConte): *a*, left urogomphus, lateral view; *b*, ninth abdominal segment, dorsal view. *c-e, Lepturoides linearis* (Linnaeus): *c*, left mediotergite of fourth abdominal segment, dorsolateral view; *d*, ninth abdominal segment, dorsal view; *e*, left urogomphus, lateral view.

FIG. 34.—Species of *Athous*.

a, c, Athous haemorrhoidalis (Fabricius): *a*, left urogomphus, lateral view; *c*, urogomphi, dorsal view. *b, A. vittatus* (Fabricius): urogomphi, dorsal view. *d, e, A. rufifrons* (Randall): *d*, urogomphi, dorsal view; *e*, left mediotergite of fourth abdominal segment, dorsolateral view. *f, A. brightwelli* (Kirby): urogomphi, dorsal view. *g, h, A. mutilatus* Rosenhauer: *g*, left urogomphus, lateral view; *h*, urogomphi, dorsal view.

FIG. 35.—*Athous cucullatus* group.

a, c, d, Athous cucullatus (Say): *a*, right mandible, dorsal view; *c*, ninth abdominal segment, dorsal view; *d*, left urogomphus, lateral view. *b, e, f, A. scapularis* (Say): *b*, nasale and subnasale, ventral view; *e*, left mediotergite of fourth abdominal segment, laterodorsal view; *f*, ninth abdominal segment, dorsal view.

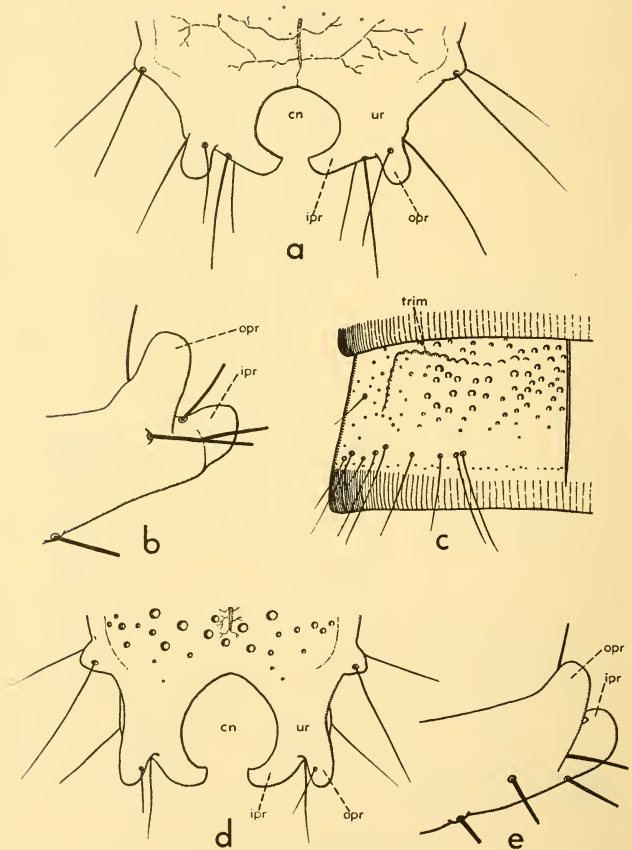


FIG. 36.—*Athous undulatus* group.

a-c, *Athous (Harminius) undulatus* (DeGeer): *a*, urogomphi, dorsal view; *b*, left urogomphus, lateral view; *c*, left mediotergite of fifth abdominal segment, laterodorsal view. *d, e*, *A. villosus* (Geoffroy): *d*, urogomphi, dorsal view; *e*, left urogomphus, lateral view.

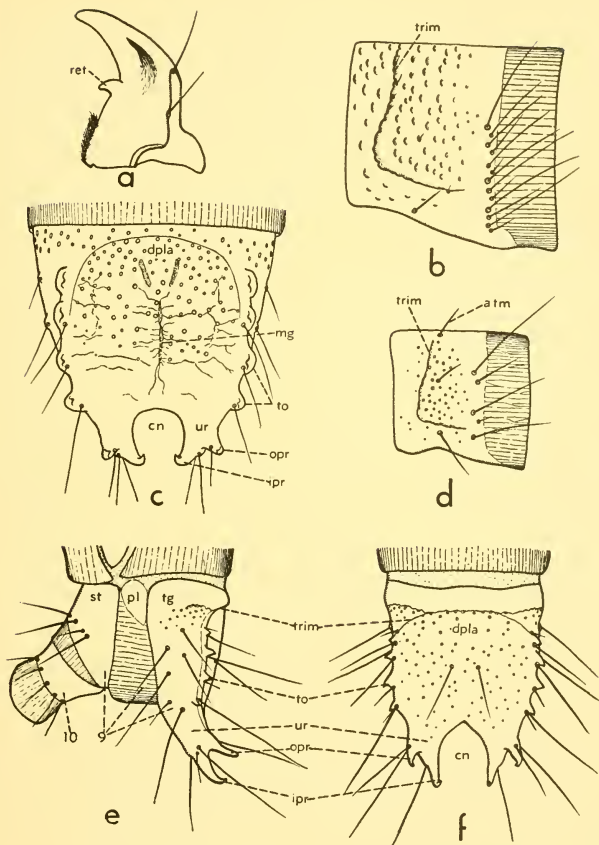
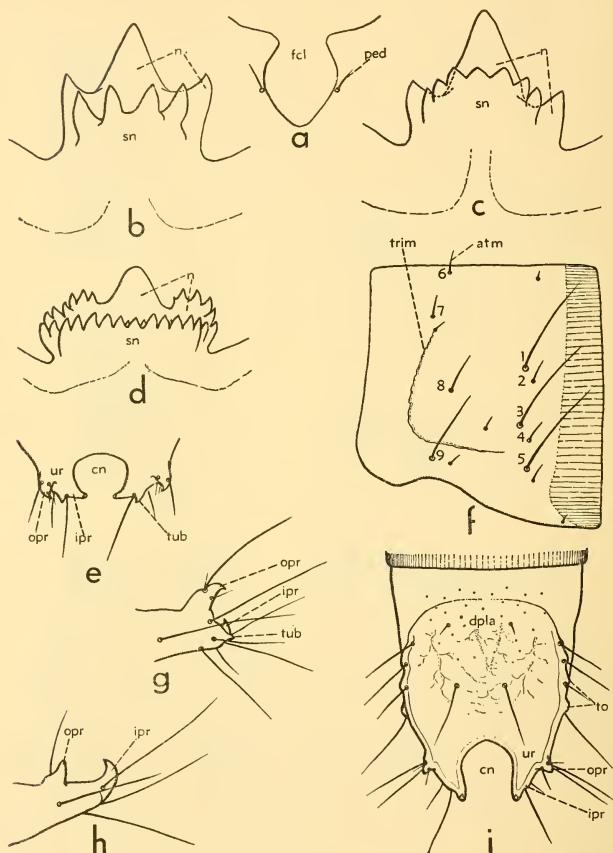


FIG. 37.—Species of *Hemicrepidius* and *Crepidomenus*.

a, *Hemicrepidius* sp., near *carbonatus* (LeConte): right mandible, dorsal view (drawn from larval exuvium of a reared specimen). *b*, *Hemicrepidius* sp. (unidentified): left mediotergite of fourth abdominal segment, dorsolateral view. *c*, *H. memnonius* (Herbst): ninth abdominal segment, dorsal view (drawn from larval exuvium of a reared specimen). *d-f*, *Crepidomenus queenslandicus* Blair: *d*, left mediotergite of third abdominal segment, dorsolateral view; *e*, ninth and tenth abdominal segments, lateral view; *f*, ninth abdominal segment, dorsal view.

FIG. 38.—Species of *Cryptohypnus*.

a, c, e, g, Cryptohypnus abbreviatus (Say): *a*, posterior part of frontoclypeal area showing adjacent setae, dorsal view; *c*, nasale and subnasale, ventral view; *e*, urogomphi, dorsal view; *g*, left urogomphus, lateral view. *b, h, i, C. riparius* (Fabricius): *b*, nasale and subnasale, ventral view; *h*, left urogomphus, lateral view; *i*, ninth abdominal segment, dorsal view. *d, f, C. funebris* Candeze: *d*, nasale and subnasale, ventral view; *f*, left mediotergite of fourth abdominal segment, dorsolateral view (showing complete complement of setae; the numbered setae are found in all known *Cryptohypnus* larvae).

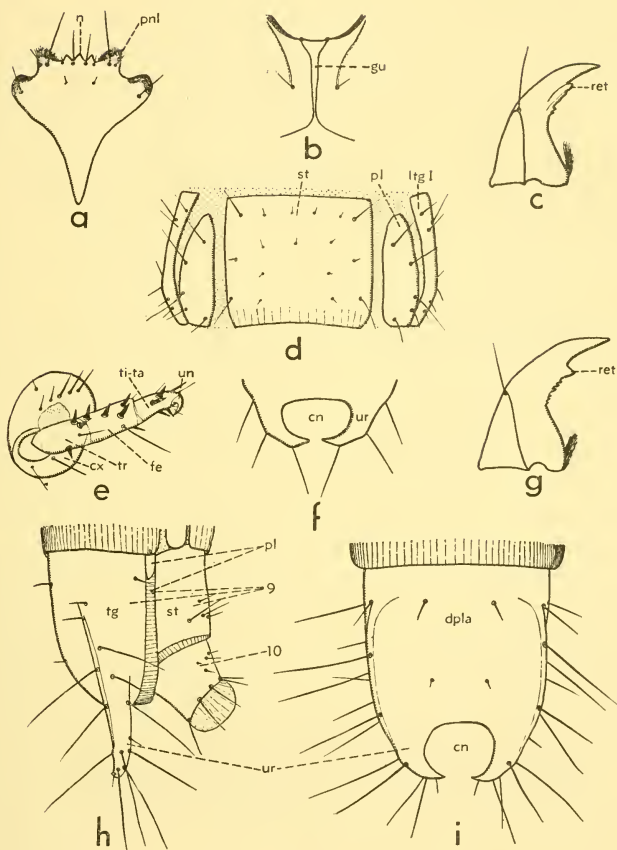


FIG. 39.—*Hypnoidus dubius* and *Hypnoidus musculus*.

a-e, h, i, Hypnoidus dubius (Horn): *a*, frontoclypeal area, dorsal view; *b*, gular area, ventral view; *c*, left mandible, dorsal view; *d*, third abdominal segment, ventral view; *e*, left mesothoracic leg, mediocephalic view; *h*, ninth and tenth abdominal segments, lateral view; *i*, ninth abdominal segment, dorsal view. *f, g, H. musculus* (Eschscholtz): *f*, urogomphi, dorsal view; *g*, left mandible, dorsal view.

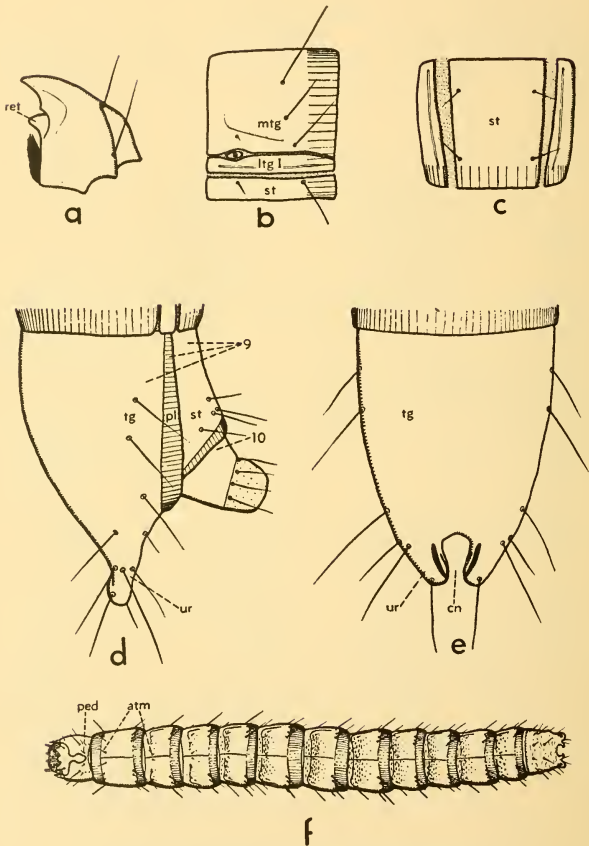


FIG. 40.—*Eanus decoratus* and *Melanactes densus*.

a-e, *Eanus decoratus* (Mannerheim): a, right mandible, dorsal view; b, third abdominal segment, lateral view; c, third abdominal segment, ventral view; d, ninth and tenth abdominal segments, lateral view; e, ninth abdominal segment, dorsal view. f, *Melanactes densus* LeConte: larva, dorsal view.



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 12

NOTE ON
FOWLE'S SPECTROSCOPIC METHOD FOR
THE DETERMINATION OF AQUEOUS
VAPOR IN THE ATMOSPHERE

(WITH ONE PLATE)

BY

L. B. ALDRICH

Director, Astrophysical Observatory



(PUBLICATION 3989)

CITY OF WASHINGTON
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NOTE ON FOWLE'S SPECTROSCOPIC METHOD FOR THE DETERMINATION OF AQUEOUS VAPOR IN THE ATMOSPHERE

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(WITH ONE PLATE)

In 1912 F. E. Fowle¹ developed a spectroscopic method for determining the amount of water vapor in a column of atmosphere vertically above the observer. This quantity he called the "precipitable water," and he defined it as "the depth of liquid water which if in the form of vapor would be contained in a column of air of the same cross-section reaching vertically to the limits of the atmosphere."

Fowle's method uses three infrared water-vapor bands, viz, ρ ($\lambda = .935\mu$), ϕ ($\lambda = 1.13\mu$) and ψ ($\lambda = 1.47\mu$). With spectrophotometric energy curves obtained at Washington by passing the radiation from a bank of Nernst glowers through a known quantity of water vapor, he studied the depths of these absorption bands as affected by changes in width of bolometer strip, slit, and other variables. The depths as expressed in the ratio $\frac{\text{deflection at bottom of band}}{\text{deflection at smooth curve above the band}}$

(or in abbreviated form, ρ/ρ_{sc} , ϕ/ϕ_{sc} , and ψ/ψ'_{sc}) he correlated with known quantities of water vapor in the path of the beam. The amount of water vapor, expressed in centimeters of precipitable water, was determined from the length of path and from wet- and dry-bulb readings taken at many points along the path of the beam. The accuracy of these water-vapor determinations he checked by absorbing with phosphorus pentoxide and calcium chloride the water vapor in known volumes of air along the path. Thus he developed a table giving for standard conditions of definition and purity of the spectrum, as controlled by slit width, bolometer strip width, time of swing of galvanometer, etc., the precipitable water corresponding to given values of ρ/ρ_{sc} and ϕ/ϕ_{sc} . This table has since been extensively used in the solar-constant work of the Astrophysical Observatory, particularly in daily determinations of the short-method function F. (see *Ann. Astrophys. Obs.*, vol. 6, p. 66).

¹ *Astrophys. Journ.*, vol. 35, p. 149, 1912; vol. 37, p. 359, 1913.

In 1947 the Astrophysical Observatory temporarily established at Miami, Fla., a solar field station, to carry out certain radiation measurements under contract with the Office of the Quartermaster

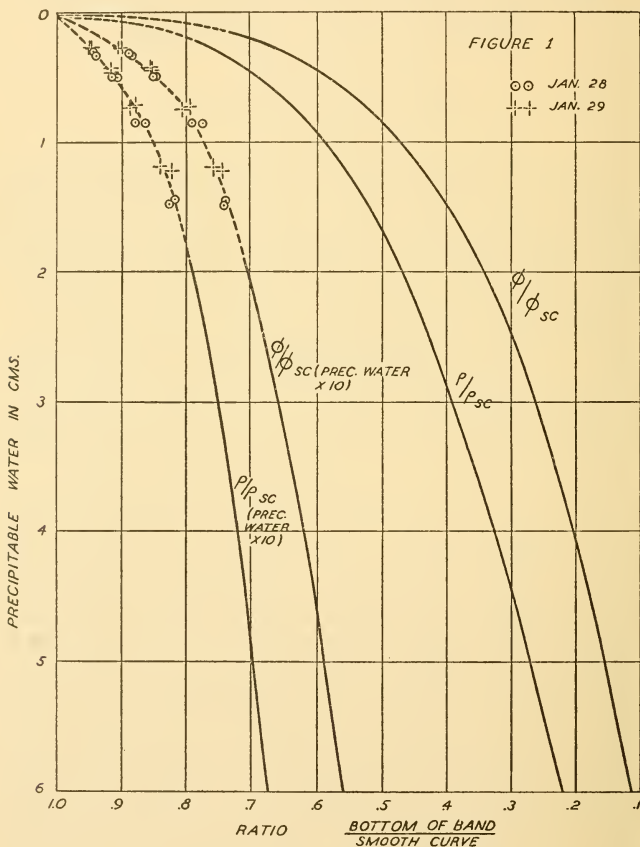


FIG. 1.—Fowle's precipitable-water curves.
(See table I.)

General. These measurements are a part of studies of the causes of deterioration of textiles, and at Miami are conducted in cooperation with the South Florida Test Service and with the General Motors Corporation on whose test field the observations are made. A part

of the equipment for this work was brought from Burro Mountain near Tyrone, N. Mex., where for some years the Smithsonian Institution maintained a high-altitude solar station.

The circumstances of a Smithsonian solar field station operating at a wet, sea-level location is unique. The only previous spectrobolometric set-up at sea level was the original Washington equipment of some 40 years ago, which Fowle used in his precipitable-water studies above mentioned. The Miami set-up thus offered opportunity to check the correctness of Fowle's precipitable-water curve.

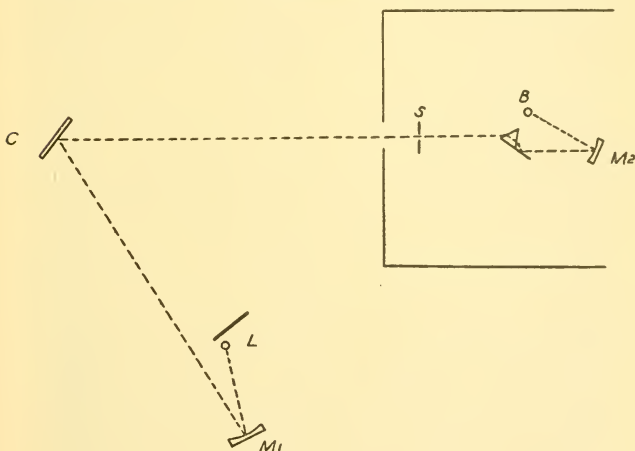


FIG. 2.—Path of beam. *L*, light source; *M*₁, *M*₂, concave mirrors, 1-m. focus; *C*, coelostat plane mirror; *S*, slit; *B*, bolometer.

We originally planned to do this in June 1948, at which time of year there is normally a maximum of atmospheric humidity. Unavoidable delays occurred, however, and bolographs were not obtained until January 1949. The following summarizes the work:

A 500-watt projection lamp was placed in the focus of a 9-inch-diameter aluminized mirror of 1 meter focal length. The assembly was mounted on a movable table in the field adjoining the station building. The approximately parallel beam from the mirror fell upon the second mirror of the coelostat and from there passed through the spectrobolometer, housed in the station building (fig. 2).

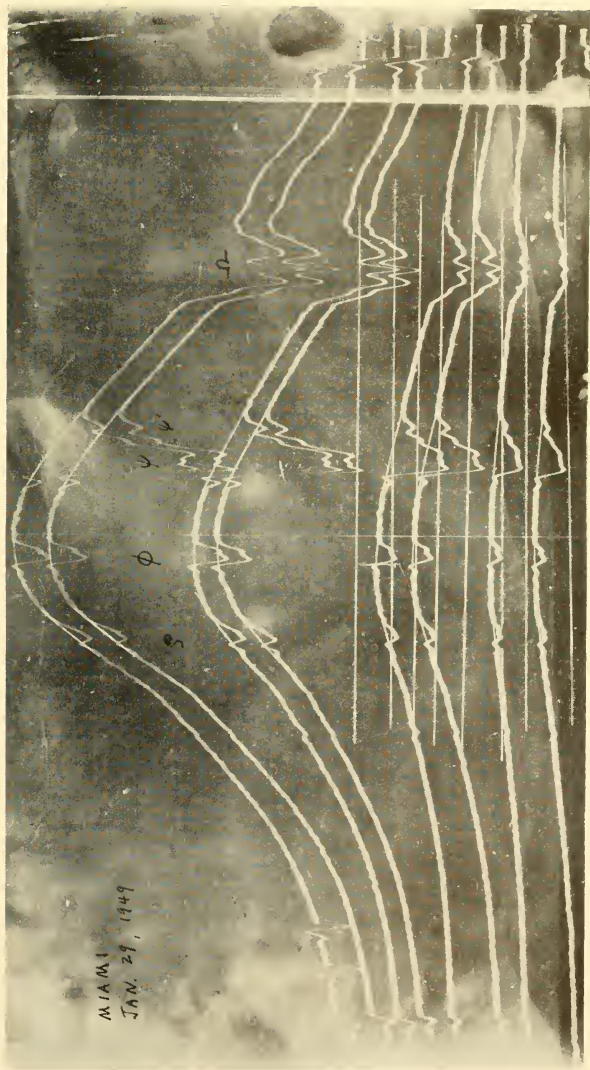
In Smithsonian solar-constant observations, standard conditions of slit width, bolometer strip width, and time of swing of the gal-

vanometer suspension are maintained. Effort is made to keep the definition constant, as measured by the depth of the Fraunhofer line "h" ($\lambda = .4102\mu$). The ratio of bottom of this band to the smooth curve over the top is kept at .845. In the bolographs of the present work these standard conditions were fulfilled.

Constancy of the lamp source was assured by the interpolation of an electronic voltage regulator capable of holding the potential across the lamp uniform within 1/10 percent. Bolographs were made on January 28 and 29 for distances lamp source to bolometer strip varying from 19 to 80 meters. Repeated wet- and dry-bulb readings were taken at various positions along the path of the beam both indoors and outdoors, during the time bolographs were being recorded. Hand-aspirated Friez psychrometers were used, checked periodically against a sling-type psychrometer.

Figure 1 gives Fowle's curves for ρ/ρ_{sc} and ϕ/ϕ_{sc} . The dotted lines extend the curves to zero water vapor. The individual points of January 28 and 29 lie on the extended curves within experimental error. Actual deviations from Fowle's values are given in table 2. As would be expected, the deviations are generally larger as the deflections become smaller.

It is gratifying that Fowle's curve appears substantially correct for the water-vapor range here tested. On January 28 the average air temperature was 73° F. and relative humidity 80 percent. On January 29 air temperature was 67° and relative humidity 90 percent.



BOLOGRAPHS OF JANUARY 29, 1949

TABLE 1.—*Fowle's standard table. Precipitable water vs. depth of band*

(For standard conditions of solar-constant observations: slit width, .3 mm.; time of single swing of galvanometer, 1.4 sec.; ratio of bottom of the Fraunhofer "h" line ($\lambda = .4102 \mu$) to smooth curve = .845.)

ρ/ρ_{sc}	ϕ/ϕ_{sc}	Precipitable water in cm.	ρ/ρ_{sc}	ϕ/ϕ_{sc}	Precipitable water in cm.
.210	.104	6.34	.510	.381	1.60
.220	.111	6.09	.520	.392	1.51
.230	.119	5.85	.530	.403	1.42
.240	.127	5.62	.540	.414	1.34
.250	.136	5.40	.550	.425	1.26
.260	.145	5.19	.560	.436	1.19
.270	.154	4.99	.570	.448	1.12
.280	.163	4.80	.580	.459	1.05
.290	.172	4.61	.590	.470	.98
.300	.181	4.43	.600	.481	.92
.310	.190	4.25	.610	.493	.87
.320	.200	4.08	.620	.504	.82
.330	.209	3.91	.630	.515	.77
.340	.217	3.75	.640	.526	.72
.350	.226	3.59	.650	.537	.67
.360	.234	3.43	.660	.548	.63
.370	.242	3.28	.670	.560	.59
.380	.251	3.13	.680	.571	.55
.390	.259	2.98	.690	.583	.51
.400	.267	2.84	.700	.594	.47
.410	.276	2.70	.710	.606	.43
.420	.285	2.57	.720	.618	.40
.430	.294	2.44	.730	.630	.37
.440	.304	2.32	.740	.642	.34
.450	.315	2.20	.750	.655	.31
.460	.326	2.09	.760	.667	.28
.470	.337	1.98	.770	.680	.25
.480	.347	1.88	.780	.693	.23
.490	.359	1.78			
.500	.370	1.69			

TABLE 2.—*Summary of January 28 and 29 data*

Date	Total distance source to bolometer (meters)	Maximum deflection (cm.)	Bolograph number	Band	Ratio	Precipitable water by Fowle's curves (cm.)	Observed value (cm.)	Difference	
1949 Jan. 28	19.44	10.80	I	ρ	.939	.032	.032	+	0
				ϕ	.889	.032		0	
			II	ρ	.936	.034	.032	+	.002
				ϕ	.885	.033		+.001	
	30.51	8.28	III	ρ	.905	.052	.050	+	.002
				ϕ	.849	.050		0	
			IV	ρ	.912	.048	.050	-	.002
				ϕ	.848	.050		0	
	51.81	3.13	V	ρ	.876	.080	.086	-	.006
				ϕ	.776	.096		+.010	
			VI	ρ	.867	.086	.087	-	.001
				ϕ	.790	.082		-.005	
	79.66	1.36	VII	ρ	.816	.145	.145		0
				ϕ	.740	.144		.001	
VIII			ρ	.825	.132	.148	-	.016	
			ϕ	.740	.144		-.004		
Jan. 29	19.44	11.10	I	ρ	.949	.027	.027		0
				ϕ	.902	.026		-.001	
			II	ρ	.947	.0275	.0278		0
				ϕ	.899	.029		+.001	
	30.51	7.23	III	ρ	.916	.046	.045	+	.001
				ϕ	.851	.046		+.001	
			IV	ρ	.916	.045	.045		0
				ϕ	.854	.045		0	
	51.81	2.92	V	ρ	.877	.073	.073		0
				ϕ	.794	.076		+.003	
			VI	ρ	.884	.074	.075	-	.001
				ϕ	.802	.074		-.001	
	79.66	1.16	VII	ρ	.823	.135	.123	+	.012
				ϕ	.742	.133		+.010	
VIII			ρ	.839	.113	.119	-	.006	
			ϕ	.756	.117		-.002		
						Total	{	+.043	
						Differences		-.046	

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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Roebling Fund

SHORT PERIODIC SOLAR VARIATIONS
AND THE TEMPERATURES OF
WASHINGTON AND NEW YORK

BY

C. G. ABBOT

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(PUBLICATION 3990)

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SHORT PERIODIC SOLAR VARIATIONS AND THE TEMPERATURES OF WASHINGTON AND NEW YORK

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In my paper read before the National Academy of Sciences in April 1949, fairly successful predictions of 55 minima of Washington temperatures for the year 1948 were discussed. The 55 dates in question were the dates when the period of 6.6456 days¹ would recur in the same phase as on January 17.0000, 1946. It was privately indicated to me, after the delivery of my paper, that certain correlation studies which had been made on New York City temperature departures raised doubts if similar results would have been obtained for that station. By the kindness of E. J. Christie, Meteorologist in Charge at New York, Weather Bureau forms 1030 giving departures from normal temperature for every day from January 1928 to date were furnished for me to study this question.

WHY EXPECT SUCH A REACTION?

Before proceeding further, let us refresh our minds on the reasons for supposing that there should be a period of 6.6456¹ days in meteorology.² Solar radiation is the source which maintains the earth's temperature and other meteorological phenomena. If the solar radiation is variable, these must be expected to vary. Daily observations by Smithsonian observers carried on at Montezuma, a mountain 9,000 feet high in the Atacama Desert of northern Chile, show that small fluctuations of the sun's output of radiation do occur. A statistical study of them showed that there is an approximately regular solar variation of about $6\frac{2}{3}$ days' period.

The departures from normal temperatures at Washington between the years 1910 and 1945 were tabulated in $6\frac{2}{3}$ -day intervals for the months of May and November, separately. On plotting the $6\frac{2}{3}$ -day

¹ As shown below a small correction now alters this period to 6.6485 days.

² See Smithsonian Misc. Coll., vol. 107, No. 4, Apr. 4, 1947.

curves for May, it was seen that a decided indication of a variation of about that period occurred, but sometimes from 1 to (rarely) 3 days before or after it was expected. However, upon scanning the whole 45 years of May values, it was clear that the period was either a little shorter than $6\frac{2}{3}$ days (best value found to be 6.6456^1 days which is about $1/55$ of a year) or else it must be about $1/54$ or $1/56$ of a year. Now turning to the tabulation for November, it was found that only the period 6.6456^1 days could serve. For if either $1/54$ or $1/56$ of a year were adopted, the November curves would be a half period out of phase with those of May.

Afterward, the solar-constant values of Montezuma, 1924 to 1945, were critically studied. They proved to exhibit this period of variation, and with perfect regularity. The displacements of from 1 to (rarely) 3 days in phase in Washington temperature departures from the normal do not occur in the solar variation. Considering the complexity of the earth, its atmosphere, and meteorological reactions, it is not surprising that such displacements of the phases of a terrestrial response to regular solar pulses should occur. But they impair the value of the solar period for forecasting purposes. It was shown, however, in Smithsonian Miscellaneous Collections, vol. 107, No. 4, that the temperature departures caused by this periodic solar variation range from 2° to 20° F. at Washington and also at St. Louis and at Helena, Mont.

PROCEDURE OF INVESTIGATION

Proceeding with the investigation of New York City temperature departures, I made monthly tables of the four or five recurrences of the 6.6456-day period in each month. These covered 21 years from 1928 to 1948, making 1,154 separate recurrences in all. The tables were based on January 17.000, 1946, so as to be comparable directly with the Washington work reported in Smithsonian Miscellaneous Collections, vol. 111, No. 6. The following sample, table 1, is for May 1929.

It will be noticed that only six values occur in lines 1 and 4 of the table and that the vacancies are distributed to the last and first columns. These adjustments take into consideration whether the fractions in the phase dates exceed 0.5 or not. The vacancies are distributed so that, in the year, as many fall in the first column as in the last. Proceeding in this way the New York data were all tabulated from 1928 to 1948 by individual monthly means. It was

then noticed that maxima and minima in the seven-column means occurred progressively later as the years went on.

CORRECTION OF THE PERIOD

By graphic methods applied to both maxima and minima, and to several different months of tabulation, it appeared that the secular displacement of features just referred to amounted to 3 days in 18

TABLE I.—*New York City temperature departures, May 1929, arranged in the 6.6456-day period*

	April	May				June	
Phase dates	28.6936	5.3392	11.9848	18.6304	25.2760	0.9216	
Temperature departures ..	-3°	-3°	1°	1°	-2°	-6°	
	5	1	-2	-8	-6	-5	-3°
	5	3	-4	10	2	-7	0
		2	-10	-14	-4	-9	-1
	-1	2	4	10	12	10	15
Mean. .	1.5	1.0	-2.2	-0.2	0.4	-3.4	2.7

years. As there are 55 recurrences of the period each year, this displacement corresponds to $\frac{3}{18 \times 55} = 0.0030$ days per cycle. It is more convenient to use numbers ending in 5 than in 6, and the accuracy of the determination does not justify the inconvenience, so, instead of 0.0030, a correction of 0.0029 was applied, making the corrected period 6.6485 days.

By subtracting and adding this number of days many times to January 17.0000, 1946, a tabulation was prepared giving dates of all expected minima of temperatures at Washington from 1928 to 1948. Applying this table also at New York it would be found whether minima, occurring there by the effect of the periodic solar variation, fall on the same dates as at Washington.

PREPARATION OF THE DATA

Using Weather Bureau forms 1030, the departures from normal temperature were tabulated, exactly as in table I, for both Washington and New York, from January 1928 to December 1948. In these tabulations the newly corrected period 6.6485 days is used. As stated above, the tabulation is based on January 17.0000, 1946.

As the reader will note in table I, this arrangement results in tables of seven columns, and these were labeled 1 to 7. Each month—

January for instance—yields first a table of either four or five lines, depending on whether some January days were required to complete lines of December or February, or whether some days from one or both of those months were required to complete lines of January.

Mean values having been taken, as in table 1, there resulted a new table of 21 lines, of 7 columns each, for each one of the 12 months of the year, the entire 12 tables covering the interval 1928 to 1948.

FREQUENCY DISTRIBUTION

From the 12 tables of mean monthly temperature departures were now read off from their 21 lines the days (1 to 7) on which maxima and minima of temperature occurred. Where identical mean departures came on more than one day, the reading was appropriately split up, as, for instance the same minimum occurring on days 1 and 7 was tabulated as $\frac{1}{2}$ at 1 and $\frac{1}{2}$ at 7.

Terrestrial responses to solar impulses lag behind their solar causes. Thus, for example, the coolest and warmest parts of the day occur several hours after midnight and noon, respectively. The lag differs from place to place, and from time to time, depending on terrestrial complexities. So it should not be expected that maxima and minima of temperatures at New York and Washington, due to a periodic solar change, would necessarily be coincident, or that at either station they would always be found at the same columns of the tables.

If, as hitherto generally supposed by meteorologists, weather is almost wholly governed by terrestrial influences, apparently accidental as to timing, then a study of the frequency of maxima and minima in my tables should show no marked preference for any columns over the others. But if, as indeed will be shown below, the regular solar periodic pulse is a principal cause of weather, then, despite the interference by terrestrial complexities, there should be found marked preferences for certain columns as seats of maxima and minima. Chance is largely subordinated by multiplicity in this study, for each month of the 12 monthly tables results from $21 \times \frac{55}{12} = 96$ recurrences of the period.

It was presumed that the lag of temperature response might differ in different parts of the year. Hence the 12 months were tabulated separately. Moreover, a great collection of unpublished studies on the terrestrial responses to 14 long-period solar variations has shown that such responses are apt to differ greatly with sunspot frequency. Hence, in each of the 12 monthly tables, the years 1928-30, 1936-41,

and 1946-48 were kept separate from the years 1931-35 and 1942-45. In anticipation, it may be remarked that slight displacements of maxima and minima seem to attend both the time of the year and the epoch of the sunspot cycle. But these displacements are so small, and the effect of the 6.6485-day period is so pronounced, that a direct mean of all the evidence, for all months and all years, shows distinctly the main features of the frequency of distribution of the temperature departure features.

TABLE 2.—*Frequency of temperature minima in the seven columns*

Lines	Station	1	2	3	4	5	6	7	No. of years
1.....	New York	52	30	30	42	25	26	47	21
2.....	Washington	44	35	23	46	26	23	55	21
3.....	New York	28	15	20	25	17	13	26	12
4.....	Washington	23	18	15	31	12	18	27	12
5.....	New York	26	15	10	17	8	13	21	9
6.....	Washington	21	17	8	15	14	5	28	9
7.....	New York	2.33	1.25	1.67	2.08	1.42	1.08	2.17	1
8.....	Washington	1.92	1.50	1.25	2.58	1.00	1.50	2.25	1
9.....	New York	2.67	1.67	1.11	1.89	0.89	1.44	2.33	1
10.....	Washington	2.33	1.89	0.89	1.67	1.56	0.56	3.10	1
11.....		+	+	-	-	±	±	+	

EXPLANATION.—Lines 1, 2 cover monthly means for all years, 1928-1948.

Lines 3, 4 cover monthly means for years of sunspot maximum.

Lines 5, 6 cover monthly means for years of sunspot minimum.

Lines 7-10 cover as lines 3-6, but are general averages for 1 year only.

Line 11 shows when years of sunspot minimum have higher frequencies.

In table 2 and figure 1 are given the frequencies with which minima in all the monthly mean tables combined (similar to table 1) fall in the seven different columns of the tabulations. For curiosity's sake the table also gives the average numbers per month of occurrences of mean minima for sunspot maximum and sunspot minimum years separately. Reducing the values to equal numbers of years, it will be seen from these latter tabulations that for both Washington and New York there is a tendency in sunspot minimum years for minima to occur with greater frequency in columns 1, 2, and 7, and lesser frequency in columns 3, 4, 5 and 6. This shows that the principal solar period has better control over terrestrial disturbances when sunspots are at minimum. But ignoring this subordinate result, the main results of the tabulation show that:

1. There is a great and nearly equal preponderance of frequency for both stations in columns 1 and 7, so that the minimum falls at about half a day after 7 in both cities.

2. There is a strong frequency in column 4, showing that another regular periodic solar variation exists of $\frac{6.6485}{2} = 3.3242$ days in period. Its phases coincide with those of the primary period whenever possible.

3. There is no appreciable difference in lag between Washington and New York in response to the solar variations. In short, the two stations behave nearly alike in all respects.

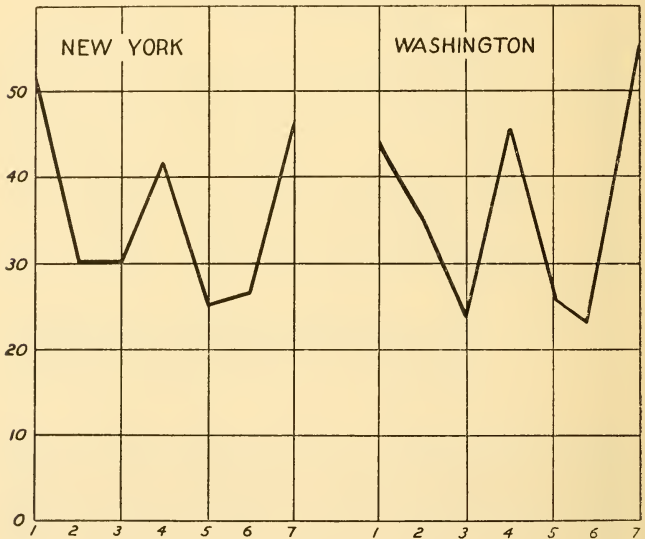


FIG. 1.

MAGNITUDE OF THE EFFECT

Owing to terrestrial interferences in lag and otherwise, and to the interference caused by the existence of the secondary solar period of half the length of the primary one, the positions of maxima and minima fluctuate. Comparatively seldom does a whole month go by without shifts of 1, 2, or rarely 3 days in the place of minima. On this account the mean monthly values seldom show the full measure of the effect of the solar change on terrestrial temperatures. However three months have been selected from many among the tempera-

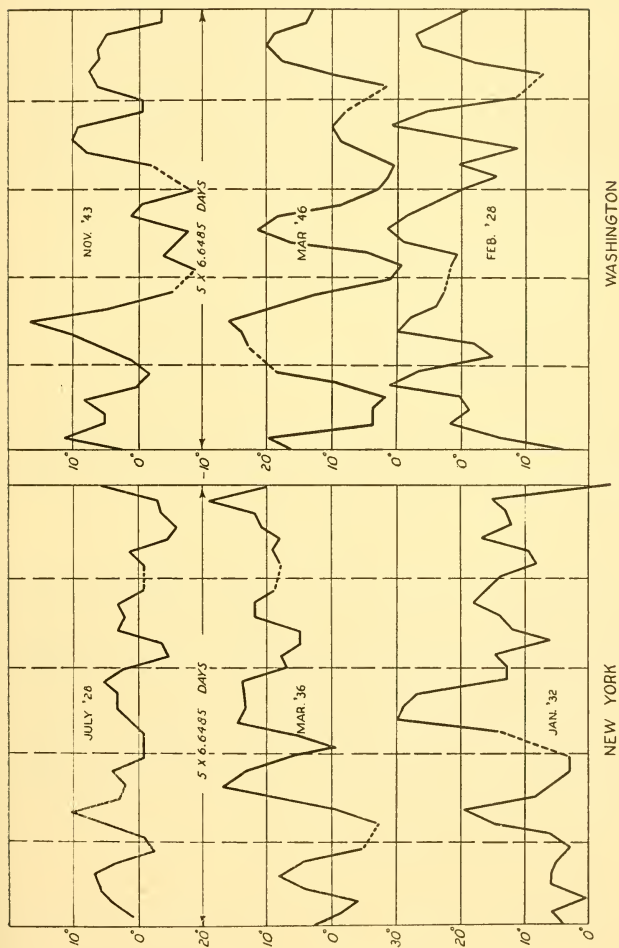


FIG. 2.

ture departures for each of the two stations, when the regularity of the periods was little disturbed during the whole month. Months were chosen fairly well distributed throughout the year. Plots of these temperature departures are given in figure 2. By drawing straight lines across the bottom of each hump, values have been read off giving roughly the numbers of degrees by which the temperatures were raised by the solar influence. As is well known, the temperature changes of all sorts are much less in July than in the cooler months of the year, in the Eastern United States. Hence it is not surprising that this appears in figure 2 and in table 3.

TABLE 3.—*Average magnitude of the temperature fluctuations in degrees F.*

New York	Washington
Jan. 1932, 12°6	Feb. 1928, 15°2
Mar. 1936, 14°2	Mar. 1946, 14°0
July 1938, 7°8	Nov. 1943, 12°4

By inspection of these exhibits one sees that throughout most of the year, in Washington and in New York, the temperature is affected either four or five times each month by a change in solar radiation, by amounts ranging from 10° to 20° F.

CONCLUSION

Contrary to the suggestion referred to at the beginning of this paper, Washington and New York respond almost alike to the short regular variations of solar radiation. Two such variations are known. The primary one has a period of 6.6485 days, and the subordinate one half that length. Thus the primary solar change recurs either four or five times each month. Temperature changes of 10° to 20° F. attend its every recurrence during most months of the year, but during summer the effect is somewhat less. The phases of the temperature changes appear to be the same at Washington and New York.

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THE ABBOT SILVER-DISK
PYRHELIOMETER

(WITH ONE PLATE)

BY

L. B. ALDRICH

Director, Astrophysical Observatory



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DESCRIPTION OF INSTRUMENT

In 1922 Dr. C. G. Abbot published a paper (The Silver-Disk Pyrheliometer, Smithsonian Misc. Coll., vol. 56, No. 19) describing his pyrheliometer, the method of use and possible errors, and listing the constants of the various instruments. Since 1922 several modifications of the instrument and of its method of use have been adopted, and some 50 additional pyrheliometers have been prepared and sold to interested institutions throughout the world. It therefore seems advisable to bring Dr. Abbot's 1922 discussion up to date.

Volume 2 of the Annals of the Astrophysical Observatory of the Smithsonian Institution (p. 36) describes the original mercury pyrheliometer which Dr. Abbot built in 1902 and from which the silver-disk pyrheliometer developed. In 1909 the form of instrument shown in cross section in figure 1 was adopted. The following description of it is taken from Dr. Abbot's paper (Smithsonian Misc. Coll., vol. 56, No. 19):

The silver disk, *a*, shown in cross-section [fig. 1], is bored radially with a hole to admit the cylindrical bulb of a thermometer, *b*. The hole in the disk has a thin lining of steel, so that a small quantity of mercury may be introduced without alloying the silver, in order to make a good heat conduction between the silver disk and the thermometer bulb. A soft cord soaked in shellac is forced down at the mouth of the hole to prevent escape of mercury, and a ring of Chatterton¹ wax is sealed over the outside of the cord to make the closure more perfect.

The thermometer, *b*, is bent at a right angle, as shown, in order to make the instrument more compact and less fragile. A nicked brass tube (shown partly cut away in the figure) supports and protects the thermometer. A slot is cut in the right-hand side of the support tube throughout almost its whole length to permit the reading of the thermometer. At the top of the support tube a short piece is removable, in order that heat may be applied to the overflow bulb of the thermometer, to dislodge mercury which sometimes collects there

¹ Picein wax has been used in recent years.

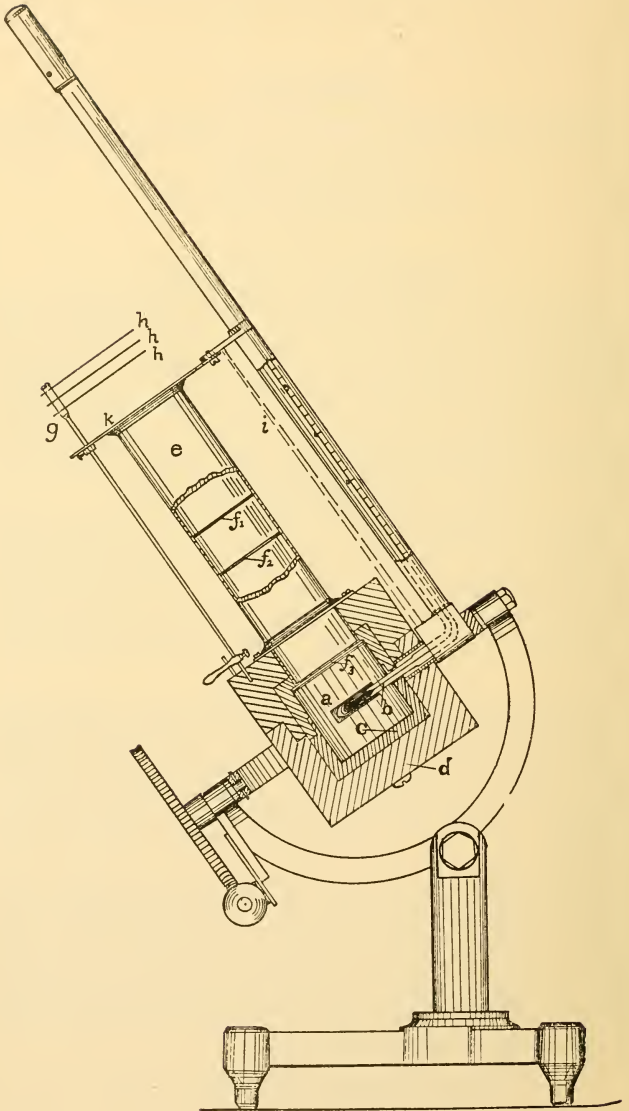


FIG. 1.—Abbot silver-disk pyrheliometer.

during transportation. The thermometer is graduated to tenths of degrees centigrade from -15° C. to $+50^{\circ}$ C. Two points, 0° and $+50^{\circ}$, are first marked on the stem by the makers, and then the thermometer is graduated by equal linear intervals without regard to the variations of cross-section of bore of the stem. Before insertion in the instrument, a careful calibration of the thermometer stem is made.

The silver disk, *a*, is enclosed by a copper cylindrical box, *c*, halved together for convenience in construction. Three small steel wires, not shown in the figure, support the silver disk. These wires lie in the plane of the center of the disk at 120° intervals apart. Midway between them are three brass screws, not shown, which may be screwed through the walls of the box, *c*, up to their heads. These screws in that position clamp the silver disk tightly. Their purpose is to prevent the breakage of the thermometer if jarred during transportation. These screws must be loosened during observations.

The copper box, *c*, is enclosed by a wooden box, *d*, to protect the instrument from temperature changes. This box is also halved together and fastened by long wood-screws, one of which is seen near the letter, *d*, in the figure.

Sunlight may be admitted through the tube, *e*. This tube is provided with a number of diaphragms, *f*₁, *f*₂, *f*₃, having circular apertures. The aperture, *f*₃, nearest the silver disk is slightly smaller than the others, and slightly smaller than the disk itself. Thus it limits the cross-section of the sunbeam whose intensity is to be measured. The entire interior of the tube, *e*, the box, *c*, and the silver disk, *a*, are painted dead black with lamp-black mixed in alcohol, with a little shellac added to cause the lamp-black to stick. To secure a fine, even coat, the mixture is filtered through cheesecloth before applying, and on the disk it is warmed with an alcohol lamp until the brush marks disappear.

A rotatable shutter, *g*, with three nicked parallel metal plates, *h h h*, is provided for cutting off the sunlight as desired. The top of the tube, *e*, carries a screen, *k*, large enough to shade the wooden box, *d*. This screen also supports the thermometer tube, and the axis of the exposing shutter just mentioned. A small hole in the part which supports the thermometer admits a little guiding beam of sunlight, *i*, whose use is to assure the observer that the instrument points toward the sun.

The pyrheliometer is carried upon an equatorial stand, as shown in the figure. A worm and wheel mechanism is provided for following the sun. No clock-work is needed, as it is sufficient for the observer to move the worm slightly two or three times a minute.

In 1927 two alterations were adopted: (1) the tube *e* was lengthened and (2) the base was enlarged to counteract top-heaviness due to the longer tube. These changes are shown in the photograph, plate 1. The short tube form of 1909 when the shutter was opened exposed each point on the silver disk to a cone of sky $10^{\circ}38'$ in diameter. Since the sun subtends a diameter less than $1/20$ th as great, the sky area exposed is at least 400 times that occupied by the sun. In very clear skies the radiation from this area of sky is negligible as compared to that from the sun. But measurement at Mount Harqua Hala in 1925²

²Annals of the Astrophysical Observatory of the Smithsonian Institution, vol. 5, p. 83.

in a very hazy sky indicated that the readings were as much as $2\frac{1}{2}$ percent too high. To diminish the error from this source all silver-disk pyrheliometers made after 1926 carried tubes 32 cm. long in place of the original 15 cm. The exposed sky area was thus reduced from .0043 hemisphere to .0013. As opportunity has arisen the following older instruments have been similarly modernized by substituting the longer tube and enlarging the base: S.I. Nos. 1, 5, 16, 17, 26, 31, 41, 42, and 44. In hazy skies the error due to sky radiation now seldom exceeds $\frac{1}{2}$ percent.

While it is possible, from a study of the dimensions and physical properties of the instrument, to reduce its readings to heat units, there are uncertainties in thus using it as an absolute standard. We have preferred to consider it as a secondary instrument, the constant of each individual pyrheliometer being determined by careful comparisons with Smithsonian standard instruments.⁸ Readings of the silver-disk instrument are proportional to the intensity of radiation of the sun, and are comparable one with another at all times and places. Multiplying the corrected readings by the constant of the instrument reduces them to true heat units.

DIRECTIONS FOR USE

These directions, with minor alterations to conform with our present practice, are taken from Dr. Abbot's paper, mentioned above.

SETTING UP

1. If the mercury column of the thermometer is broken, remove the little screw at the side near the upper end of the nickel-plated tube, and take off the upper portion of the tube. Then heat the exposed stem cavity of the thermometer gently in a smoky flame (a match flame is good) until the mercury is expelled from the cavity. Then, holding the thermometer vertical, shake the instrument repeatedly with a downward jerk until the mercury columns join.

2. Remove the two little ivory or fiber plugs (using pliers if necessary) and unscrew the two brass screws under them, and also unscrew the third similar screw seen through the trunnion on the other side of the case. About three complete turns of each screw is proper. Insert the two ivory plugs. *When packing the instrument again for*

⁸ Descriptions of Smithsonian absolute standard pyrheliometers are given in *Annals of the Astrophysical Observatory of the Smithsonian Institution*, vol. 3, p. 52; vol. 6, p. 5; *Smithsonian Misc. Coll.*, vol. 87, No. 15; vol. 92, No. 13; vol. 110, No. 5.

a journey, screw in the three screws as far as they will go. Their purpose is to clamp the silver disk to protect the thermometer during transportation.

3. Unscrew the two pivots from the sides of the ring of the mounting, insert the pyr heliometer so that the thermometer is *not* next to the worm wheel, and screw in the pivots.

4. Unclamp the half ring and set the polar axis approximately for the latitude of the place. The thermometer should be next to the *upper* end of the axis.

ADJUSTMENTS

5. For quick adjustment in right ascension guide the pyr heliometer with one hand and loosen the lower right-hand milled screw (as seen from the upper end of the polar axis). The worm may then be lowered out of engagement with the wheel and the change made.

6. To follow the sun, adjust in right ascension and declination until the sun shining through the little hole in the upper plate forms its image on the scratched spot on the nicked piece below. When exposing to solar radiation rotate the worm screw a little (about once every half minute) to follow the sun.

7. When about to observe, push aside the cover, leaving only the shutter to shade the silver disk. When through with each series of readings, close the cover to keep out dust.

OBSERVATIONS

8. When reading the thermometer the observer should hold his head so that the reflection of each dark line of the scale near the degree to be observed, as seen in the mercury thread, is coincident with the corresponding dark line. This prevents parallax errors of reading.

9. Having adjusted the instrument to point at the sun and opened the cover, read the thermometer exactly at 20 seconds after the beginning of the first minute. Read again after 100 seconds, or at the beginning of the third minute, and immediately after reading open the shutter to expose to the sun. Note that the instrument is then correctly pointed. After 20 seconds read again. After 100 seconds more (during which the pointing is corrected frequently), or at the beginning of the fifth minute read again, and immediately close the shutter. After 20 seconds read again. After 100 seconds read again, or at the beginning of the seventh minute. Continue the readings in the above order, as long as desired. Readings should be made within $\frac{1}{2}$ second of the prescribed time. Hold the watch directly opposite the degree to be observed, and close to the thermometer. Read the hundredths of degrees first, the degree itself afterward.

10. For results not requiring the highest accuracy the above described method of reading is satisfactory. As the result of long experience, we now use for greater accuracy several refinements of this method, as follows:

(a) A special reading glass is used. It consists of a small eyepiece of about 4 cm. focal length, mounted so that it can easily be held against and moved along the thermometer stem. In the focus exactly in the center of the field is a sharp needle point. By taking readings when the needle point is opposite the top of the mercury column, parallax errors are eliminated.

(b) Any simple device to beat regular intervals (such as 1, 5, or 10 seconds) permits the observer to concentrate on reading the thermometer instead of trying to read both watch and thermometer at the same time. Such a device also eliminates possible error due to eccentricity of the second hand of the watch.

(c) The instrument is set out in the sun at least 15 minutes before starting to read, and the shutter opened to the sun for about 1 minute during this period. In making a series of observations, the second set of readings is started 20 seconds after completing the first set of six readings. Thus a 4-minute shaded period occurs between each 2 minutes of exposure. Each set of six readings is quite independent.

11. For example:

Reading	1	2	3	4	5	6
Time	11 ^h 55 ^m 20 ^s	57 ^m 00 ^s	57 ^m 20 ^s	59 ^m 00 ^s	59 ^m 20 ^s	0 ^h 01 ^m 00 ^s
Reading	15°12	14°25	14°80	17°58	17°36	16°09
Condition ..	Shaded		Exposed		Shaded	
	Air temperature 15°.		Pyrheliometer "S.I.Q."			

12. Subtract readings (2) from (1); (3) from (4); (6) from (5).

13. Take the algebraic means

$$\frac{(1) - (2) + (5) - (6)}{2}$$

and to them add [(4) - (3)].

14. Call this result R_1 . Find roughly the mean temperature T_1 during the interval of exposure (3) to (4).

15. Add to R_1 the percentage correction for graduation furnished with the instrument, then, after correcting, add to R_1 , $K[(T_1 - 30^\circ)R_1]$. K is a constant furnished with the instrument. If the prevailing temperature of the air differs much from 20° , add $0.0014 R$ for each 10° the air temperature falls below 20° . The result (which we will call R_1^1) is the final rate of rise per 100 seconds during the exposure (3) to (4) as reduced to the standard bulb temperature of 30° , and standard stem temperature of 20° .

16. (Note.) The approximate method of procedure stated in (13) and (15) is much easier than the exact method, and having been found by experiments to yield closely comparable results under all circumstances of use, within the error of measurement, it has been adopted, and the standardization of the instrument is made by this method.

17. To reduce the result R_1 to standard calories per square centimeter per minute, or to the Smithsonian scale of 1913, multiply by the factors furnished from the Smithsonian Institution with each instrument.

18. Example of reduction:

Number	1	2	3	4	5	6
Reading	15°12	14°25	14°80	17°58	17°36	16°00
Differences		0°87	2°780			1°27
Cooling correction..	....		1°070			....
R_1 .....	....		3°850			....
T_1 .....	....		16°2			....
Scale correction ...	-0.0020 R_1 =		-0°008			....
$KR(T-30^\circ)$	-(0.0011)(13.8) R_1 =		-0°058			....
Air correction	+0.0007 R_1 =		+0°003			....
R_1 .....	....		3°787			....

PRECAUTIONS

Constant watchfulness and care are needed to keep the instrument in best condition. For example, it should not be inverted or jarred, thus keeping the mercury column and the wax bond between thermometer and silver disk intact. The blackening of the silver disk should be examined periodically. If there is evidence of specks or spottedness, the surface should be carefully brushed with a soft camel's hair brush fastened to a long slender handle. The cover at the end of the tube should be kept closed when not in use. With care the blackness remains unchanged over many years. Our two substandard silver-disk instruments, A.P.O. No. 8_{bis} and S.I. No. 5 are evidence of this. Repeated comparisons against the absolute water-flow pyr heliometer over a period of 20 years have shown no evidence of change.

A silver-disk pyr heliometer ready for shipment, including standardization and boxing, costs the Smithsonian Institution about \$200. While it is not desired to manufacture them extensively, it has been our practice to prepare and sell these pyr heliometers to individuals and institutions likely to use them for valuable and regular solar observations. The special reading glass above mentioned can be furnished for \$10 additional.

*Adopted constants of silver-disk pyrheliometers**Smithsonian pyrheliometry, scale of 1913*

Instru- ment	Present constant	Location and remarks
S.I. 1.....	0.3733	U. S. Weather Bureau, 1910. Modernized, 1929.
S.I. 2.....	0.3743	Observatoire Physique Central Nicolas, St. Peters- burg, Russia, 1910 (loan); National Observatory, Rio de Janeiro, Brazil, 1912.
S.I. 3.....	0.3625	Conservatoire des Arts et Métiers, Paris, France, 1911.
S.I. 4.....	0.3713	Royal University of Naples, Italy, 1911. Destroyed in World War II.
S.I. 5.....	0.3715	U. S. Department of Agriculture, Physical Laboratory, 1910. Modernized, 1931. On loan to Astrophysical Observatory since 1926.
S.I. 6.....	0.3666	Oficina Meteorológica, Buenos Aires, Argentina, 1911.
S.I. 7.....	0.3638	Do.
S.I. 8.....	0.3774	Central Observatory, Madrid, Spain, 1912.
S.I. 9.....	0.3738	Imperial College of Science and Technology, London, England, 1911.
S.I. 10.....	0.3762	Königlich Preussisches Meteorologisches Institut, Ber- lin, Germany, 1911.
S.I. 11.....	0.3769	Meteorological Observatory, Teneriffe, Canary Is- lands, 1911.
S.I. 12.....	0.3631	Königlich Preussisches Meteorologisches Institut, Ber- lin, Germany, 1912.
S.I. 13.....	0.3617	Schweizerische Meteorologische Centralanstalt, Zu- rich, Switzerland, 1912.
S.I. 14.....	0.3721	University of Toronto, Toronto, Canada, 1912. Mod- ernized, 1937.
S.I. 15.....	0.3609	National Bureau of Standards, Washington, D. C., 1912.
S.I. 16.....	0.3634	University of Arizona, Tucson, Ariz., 1912. Modern- ized, 1929. Sent to Service Botanique, Tunis, 1932.
S.I. 17.....	0.3629	Harvard College Observatory Station, Arequipa, Peru, 1912. Sent to Smithsonian Observing Station, Calama, Chile, 1919. Modernized, 1929.
S.I. 18.....	0.3774	Observatorio Nacional, Rio de Janeiro, Brazil, 1913.
S.I. 19.....	0.3737	Aeronautisches Observatorium, Lindenberg, Germany, 1913.
S.I. 20.....	0.3657	Italian Indo-Asiatic Expedition, 1913. Returned to Washington, 1916. Repaired, 1919. Sent to Observ- atory, Helwan, Egypt, 1920.
S.I. 21.....	0.3711	Aeronautisches Observatorium, Lindenberg, Germany, 1913.
S.I. 22.....	0.3778	Observatorio Astronomico Nacional, Tacubaya, Mex- ico, 1913.
S.I. 23.....	0.3683	Landwirtschaftliches Institut, Moscow, Russia, 1914.
S.I. 24.....	0.3713	Meteorological Observatory, Teneriffe, Canary Islands, 1914.
S.I. 25.....	0.3717	Do.

Instru- ment	Present constant	Location and remarks
S.I. 26.....	0.3741	Meteorological and Geophysical Service, Batavia, Java, 1914. Modernized and returned, 1947.
S.I. 27.....	0.3679	Manila Observatory, Manila, P. I., 1915.
S.I. 28.....	0.3639	Meteorological Office, London, England, 1915.
S.I. 29.....	0.3674	Calama, Chile, Smithsonian South American Expedition, 1918.
S.I. 30.....	0.3622	Do.
S.I. 31.....	0.3748	Jewish Consumptives Relief Society, Edgewater, Colo., 1920. Repaired, modernized, and sent to Carnegie Institution, Colorado and California, 1931.
S.I. 32.....	0.3691	Mount Harqua Hala, Ariz., Smithsonian Solar Observing Station, 1920.
S.I. 33.....	0.3755	Reale Osservatorio Astronomico di Capodimonte, Naples, Italy, 1921.
S.I. 34.....	0.3730	Riverside College Observatory, Sydney, Australia, 1921. Turned over to Commonwealth Observatory, Mount Stromlo, 1946.
S.I. 35.....	0.3648	Do.
S.I. 36.....	0.3640	Institutul Meteorologic Central, Bucharest, Roumania, 1922.
S.I. 37.....	0.3648	University of Lemberg and Warsaw, Lemberg, Poland, 1922.
S.I. 38.....	0.3726	Argentine Meteorological Service, La Quiaca, Argentina, 1924.
S.I. 39.....	0.3764	Do.
S.I. 40.....	0.3553	Institut de Physique du Globe, Paris, France, 1924.
S.I. 41.....	0.3697	Observatory on Zugspitze, Germany, 1924 (loan). Modernized, 1927. Sent to Institute of Meteorology, Nanking, China, 1929.
S.I. 42.....	0.3679	Mount Harqua Hala, Ariz., 1923. Modernized, 1932, and sent to Carnegie Institution, Colorado and California, as substitute for S.I. 16.
S.I. 43.....	0.3735	Stellenbosch University, South Africa, 1924.
S.I. 44.....	0.3793	Meteorological Service, Rio de Janeiro, Brazil, 1925. Modernized and returned to Brazil, 1928.
S.I. 45.....	0.3658	University of Aberdeen, Scotland, 1925.
S.I. 46.....	0.3705	Meteorological Bureau, Riga, Latvia, 1925.
S.I. 47.....	0.3735	Smithsonian Solar Observing Station, Mount Brukaros, Southwest Africa, 1926. Smithsonian Solar Observing Station, Calama, Chile, 1932. <i>Note</i> .—No. 47 and No. 48 have special 80-cm. tubes.
S.I. 48.....	0.3827	Do.
S.I. 49.....	0.3586	Battle Creek College, Mich., 1927.
S.I. 50.....	0.3800	Physikalisch-Meteorologisches Observatorium, Davos, Switzerland, 1927. Repaired and returned to Davos, 1934.
S.I. 51.....	0.3755	Meteorological Office, Simla, India, 1927.
S.I. 52.....	0.3787	University Observatory, Kiel, Germany, 1927.

Instrument	Present constant	Location and remarks
S.I. 53	.....0.3797	Commonwealth Solar Observatory, Canberra, Australia, 1928. Repaired and returned to Australia, 1937.
S.I. 54	.....0.3824	Commonwealth Solar Observatory, Canberra, Australia, 1928. Repaired and returned to Australia, 1939.
S.I. 55	.....0.3848	University of Illinois, Department of Botany, Urbana, 1928.
S.I. 56	.....0.3742	Universitäts-Sternwarte, Kiel, Germany, 1928.
S.I. 57	.....0.3818	Institut Scientifique Chérifien, Rabat, Morocco, 1929.
S.I. 58	.....0.3831	Oporto Observatory, Portugal, 1929.
S.I. 59	.....0.3851	University of Arizona, Tucson, 1930.
S.I. 60	.....0.3945	American Society of Heating & Ventilating Engineers, Pittsburgh, Pa., 1931. Repaired and returned to Pittsburgh, 1945.
S.I. 61	.....0.3867	Meteorological Service of Martinique, Fort de France, 1932.
S.I. 62	.....0.3960	Do.
S.I. 63	.....0.3821	Blue Hill Meteorological Observatory, Milton, Mass., 1932. Repaired and returned to Blue Hill, 1941.
S.I. 64	.....0.3870	Laboratoire Actinométrique de l'Observatoire de Trappes, France, 1933.
S.I. 65	.....0.3913	Institute of Meteorology, Nanking, China, 1933.
S.I. 66	.....0.3868	Institut de Physique du Globe, Paris, France, 1934.
S.I. 67	.....0.3877	Tananarive Observatory, Madagascar, 1935.
S.I. 68	.....0.3788	Institut de Physique du Globe, Paris, France, 1935.
S.I. 69	.....0.3849	Geophysical Observatory, Pilar, Argentina, 1936.
S.I. 70	.....0.3816	Do.
S.I. 71	.....0.3737	Commonwealth Solar Observatory, Canberra, Australia, 1936. Repaired and returned to Australia, 1937.
S.I. 72	.....0.3820	Commonwealth Solar Observatory, Canberra, Australia, 1936. Repaired and returned to Australia, 1939.
S.I. 73	.....0.3789	Eppley Laboratories, Newport, R. I., 1937. New thermometer inserted and returned, 1939.
S.I. 74	.....0.3962	University of Minnesota, Minneapolis, Minn., 1937.
S.I. 75	.....0.3847	R. Dvorak, Agent, Prague, Czechoslovakia, 1938.
S.I. 76	.....0.3876	Observatório Central Meteorológico, Lisbon, Portugal, 1940.
S.I. 77	.....0.3922	Geophysical Institute, University of Coimbra, Portugal, 1940.
S.I. 78	.....0.3926	U. S. Weather Bureau, Washington, D. C., 1944.
S.I. 79	.....0.3736	Physics Institute, Helsinki University, Finland, 1946.
S.I. 80	.....0.3776	Hebrew Technical College, Haifa, Palestine, 1947.
S.I. 81	.....0.3871	Institute for Advanced Learning, Dublin, Ireland, 1949.

Various A.P.O. instruments

Instrument	Constant	Location and remarks
A.P.O. IV	0.5118	Copper disk. 1906. Mount Wilson, Calif.
A.P.O. VII	0.5072	Copper disk. 1906. Mount Wilson, Calif.
A.P.O. VIII	0.5150	Copper disk. 1906. U. S. Weather Bureau and Mount Wilson.
A.P.O. 8	0.3760	First silver-disk instrument. 1909. Washington and Mount Wilson. Repaired 1910 and called A.P.O. 8 _{b1s} .
A.P.O. 8 _{b1s}	0.3786	Modernized 1927. Reserved at Washington for comparisons only.
A.P.O. 9	0.3631	Built 1910. Used at Washington, Mount Wilson, Mount Whitney, Algeria, Arizona. Modernized 1928 and called A.P.O. 9 _{b1s} .
A.P.O. 9 _{b1s}	0.3684	Zentralanstalt für Meteorologie und Geodynamik, Vienna, Austria, 1928.
A.P.O. 10	0.3720	Built 1923. Sent to Harqua Hala and Table Mountain.
A.P.O. 11	0.3675	Sent to Mount Brukkaros, Southwest Africa, 1925. Modernized and sent to Mount St. Katherine, Egypt, 1933. Repaired 1938 and sent to Tyrone, N. Mex., Miami, Fla., and Table Mountain, Calif.
A.P.O. 12	0.3618	Table Mountain, Calif., 1928.
A.P.O. 13	0.3893	Mount St. Katherine, Egypt, 1932. Rebuilt 1938 and sent to Tyrone, N. Mex., Miami, Fla., and Table Mountain, Calif.
A.P.O. 14	0.3854	Mount St. Katherine, 1932; Tyrone, N. Mex., Miami, Fla., Table Mountain, Calif.



ABBOT SILVER-DISK PYRHELIOMETER, WITH LONG TUBE ADOPTED 1927

SMITHSONIAN MISCELLANEOUS COLLECTIONS

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(WITH 12 PLATES)

BY

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THE ROLL CALL OF THE IROQUOIS CHIEFS
A STUDY OF A MNEMONIC CANE FROM THE
SIX NATIONS RESERVE¹

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(WITH 12 PLATES)

INTRODUCTION

Canes from American Indian tribes are not uncommon in museum collections. Frequently the sticks are carved or ornamented in diverse ways but, unfortunately, in most instances the specimens are accompanied by but meager data concerning their general significance and use apart from their obvious utilitarian purpose. Consequently Indian canes constitute somewhat of a problem to curators of ethnological collections. It may be inferred that decorated canes summoned the best talents of tribal artists who carved in the round or engraved designs reflecting the characteristic style of tribe and region, but lacking collectors' field notes, the symbolic intent of the adornments, if any, cannot be known. Such was the case with Iroquois chiefs' canes and with one, in particular, which is the subject of the present study.

Americanists will recall that in the Southwest a staff, now an American cane, is a symbol of authority for Pueblo governors, as it was in Spain, and that staffs also serve as fetishes (White, 1932, p. 60; Parsons, 1932, pp. 251-252; Bunzel, 1932; Aberle, 1948, p. 25). The widespread use of notched or marked sticks for mere numeration is abundantly documented in the literature (Mallery, 1893, p. 227). Dakota, Hidatsa, and Shoshoni noted the number of days traveled by notching a stick; Iowas visiting Paris in 1843 manifested amazement and wonder at outlandish European custom, counting the number of French women they saw leading dogs on the streets

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and making a list with pencil and paper that specified the number of dogs seen, size, whether leashed, carried, or perambulated (Catlin, 1848, vol. 2, p. 221). Early travelers going from the British colonies to various southern and western tribes remarked the custom of keeping the date of an appointment by using notched sticks, a bundle of sticks, or a knotted string—one unit being discarded each day until the date of the meeting (Brinton, 1885, pp. 59-62; Swanton, 1928, p. 704; 1946, pp. 610-613). Even now the Iroquois send out notched invitation sticks summoning delegates to religious councils. One notch is destroyed each day, until the holder arrives on the appointed day of the council and returns the stripped stick and the short string of attached wampum. From Virginia north to New England, the distribution of the notched-stick memorandum extended westward through the Iroquoian tribes toward the Plains (Flannery, 1939, p. 81).

The literature on American aboriginal chronological records has expanded considerably since the discovery of the *Walam Olum* or "red score" of the Delawares by Rafinesque in 1820 and its publication by D. G. Brinton in 1885. In the *Walam Olum* the Delawares reduced a genesis myth, a migration legend, and a genealogy of chiefs to a series of symbols for remembering the text of a chant. Five sections of the chant were segregated, the characters were burned or carved and then painted red on as many wooden boards, and presumably these were of a convenient size for bundling. Later the record was reduced to writing, but the manuscript as well as the original slabs have disappeared. Similar records from the Plains were painted on skins or drawn in notebooks and came into prominence when Mallery discovered and published the Dakota Winter Counts. James Mooney monographed the Kiowa calendars (1898).

In the Southwest, Russell (1908, pp. 35, 104-105) reported no fewer than five notched-stick calendars among the Pima, and the nearby Maricopa of the Gila River had identical calendar sticks, bearing notches for each year, but "all the sticks of both peoples were derived from a single prototype made after 1833." (Spier, 1933, pp. 138 ff.)

Throughout the eastern forests in the eighteenth century war memorials emblazoned on the peeled trunks of great trees stood on eminences or at important river crossings to recall to whomever might read them the achievements of great war captains. "These drawings in red by the warriors . . ." were sometimes ". . . legible for fifty years after a hero" had died, preserving the memory of his deeds for many years (Zeisberger, 1910, p. 145). A character-

istic notice proclaimed a war party, their number, town, tribe, how many of each tribe, tribal affiliation of the leader, their mission, and how many days they were out; returning, the party marked the number of scalps taken, the number of captives, and their own losses. The characters were highly conventionalized so as to be readily intelligible to neighboring tribes. Heckewelder (1876, p. 130) remarks that all nations can do this, but they do not all have the same marks; "yet I have seen the Delawares read with ease the drawings of the Chipeways, Mingoes, Shawanoes, and Wyandots on similar objects."

The warriors of the Iroquois Longhouse advertised military supremacy over neighboring tribes in a similar way. Seneca war heraldry was first described and illustrated in 1666 in a Paris Document that was attributed to Father Francois, the Recollet by the author of a later document, dated 1736, which O'Callaghan has ascribed to Joncaire (O'Callaghan, 1849, vol. 1, p. 23). "The Nine Iroquois Tribes. 1666 (Paris Doc., I.)" (pp. 1-8, 9, 10-11) is the best early account of Seneca clan organization; it says:

When they go to war, and wish to inform those of the party who may pass their path, they make a representation of the animal of their tribe, with a hatchet in his dexter paw; sometimes a sabre or club; and if there be a number of tribes together of the same party, each draws the animal of his tribe, and their number, all on a tree from which they remove the bark. The animal of the tribe which heads the expedition is always the foremost.

* * *

On their return, if they have prisoners or scalps, they paint the animal of the tribe to which they belong, rampant (*debout*) with a staff on the shoulder along which are strung the scalps they may have, and in the same number. After the animal are the prisoners they have made, with a *chichicois* (or gourd filled with beans which rattle), in the right hand. If they be women, they represent them with a *Cadenette* or queue and a waistcloth.

If there be several tribes in the war party, each paints the animal of his tribe with the scalps and prisoners it has made, as before, but always after that which is head of the party. [Pp. 4-5.]

* * *

When they have lost any men on the field of battle they paint them with the legs in the air, and without heads and in the same number as they have lost; and to denote the tribe [clan] to which they belonged, they paint the animal of the tribe [clan] of the deceased on its back, the paws in the air, and if it be the chief of the party that is dead, the animal is without the head.

If there be only wounded, they paint a broken gun which however is connected with the stock, or even an arrow, and to denote where they have been wounded, they paint the animal of the tribe [clan] to which the wounded belonged with an arrow piercing the part in which the wound is located; and if it be a gunshot they make the mark of the ball on the body of a different color.

If they have sick and are obliged to carry them, they paint litters (*boyards*) of the same number as the sick, because they carry only one in each litter. [P. 6.]

Whereupon the author proceeds to illustrate the same in two plates, which have been reproduced frequently; and besides the printed explanations, the legend on the second plate is translated to say: "The Portrait of a Savage on a board in their cabin on which they ordinarily paint, how often he has been to war, how many men he has taken and killed."

If such were Seneca war records, they were probably typical of all the Five Nations because Lafitau (1724, vol. 2, p. 164 apud) and Colden (1922, vol. 1, p. xxv) speak with familiarity of the painted records of the Mohawk, the eastern member of the Confederacy. Says Colden:

. . . they always peel a large Piece of the Bark from some great Tree; they commonly chuse an Oak, as most lasting; upon the smooth side of this Wood they, with their red Paint, draw one or more Canoes, going from Home, with the Number of Men in them paddling [sic], which go upon the Expedition; and some Animal, as a Deer or Fox, an Emblem of the Nation against which the Expedition is designed, is painted at the Head of the Canoes; for they always travel in Canoes along the Rivers . . . as far as they can.

After the Expedition is over, they stop at the same Place in their Return . . . they represent on the same, or some Tree near it, the Event of the Enterprize, and now the Canoes are painted with their Heads turned towards the Castle; the Number of the Enemy killed, is represented by Scalps painted black, and the Number of Prisoners by as / many Withs, (in their Painting not unlike Pot-hooks) ² with which they usually pinion their Captives. These Trees are the Annals, or rather Trophies of the Five Nations: *I have seen many of them*; ³ and by them, and their War Songs, they preserve the History of their great Achievements. [Pp. xxv-xxvi.]

War posts bearing the painted achievements of war leaders are reported from the Onondaga, Cayuga, and Seneca cantons during the eighteenth century, and they are recalled quaintly by the place named "Painted Post" at the junction of the Cohocton and Chemung Rivers near Corning, N. Y. (Beauchamp, 1905, pp. 135-138). A Seneca war chief named Hiokatoo (Hagido-wa, great spear point) who is described by Mary Jemison as her second husband, had such a post on which he recorded his military exploits and other matters he thought worthy of note.

In order to commemorate great events, and preserve the chronology of them, the war Chief in each tribe keeps a war post. This post is a peeled stick of timber, 10 or 12 feet high, that is erected in the town. For a campaign they make, or rather the Chief makes, a perpendicular red mark, about three inches long

² Colden here refers to prisoner ties (Willoughby, 1938) which bespeaks a certain familiarity with the Mohawk, not credited to him by later historians. See Hunt, 1940, p. 185.

³ Italics added.

and half an inch wide; on the opposite side of this, for a scalp, they make a red cross, thus, +; on another side, for a prisoner taken alive, they make a red cross in this manner, X, with a head or dot, and by placing such significant hieroglyphics in so conspicuous a situation, they / are enabled to ascertain with great certainty the time and circumstances of past events. [Seaver, 1932, pp. 176-177.]

Pictorial and war records in red paint were quite familiar to Sir William Johnson, who on occasion was not above marching at the head of a procession of chiefs singing on the path to a Condolence Council (Beauchamp, 1907, p. 393); although no mnemonic cane is mentioned in either description, in his celebrated letter of February 28, 1771, to Dr. Arthur Lee, who had requested identification of signatures to a deed of 1726, Johnson, then at the height of his power and operating knowledge on Indian customs, manners, and languages, is at some pains to explain their want of writing. He says:

. . . the Mohocks . . . in things of much Consequence . . . usually delineate a Steel, such as is used to strike Fire out of Flint, which being the Symbol of their Nation, This Steel they call *Canniah*—& themselves *Canniungaes*, . . . [But he is at a loss to derive this from "flint" itself.]

The Tuscaroras I omit as they are a southⁿ people not long introduced into the Alliance making the 6 nat^a.

The Oneidas . . . have in use [as] Symbols, a Tree, by which they w^d Express *Stability*. But their true Symbol is a Stone *Onoya*, and they call themselves *Onoyuts* a particular Inst^o of wch I can give from an Expedit^t I went on to Lake St. Sacrament in 1746, when to shew the Enemy the strength of our Indⁿ Alliances I desired Each Nation to affix their Symbol to a Tree [to alarm] the French: the Oneydas put up a stone wch they painted Red.⁴ [P. 432.]

The Onondagas . . . are somewhat better versed in the Customs of their ancestors, they call themselves people of the Great Mountain. [P. 432.]

The Cayugas . . . have for their Symbol a pipe.

The Senecas are the most numerous & most distant of the six Nat^s have sev^l Towns & Symbols from wch however little can be understood . . . [P. 433.]

* * *

But tho it does not appear that they had the use of Letters yet the traces of Government may still be seen, and there is reason to believe that they made use of Hieroglyphics Tho they Neglect them at present, . . . But theirs are drawn to the utmost of their skill to represent the thing intended, for Instance, when they go to War, they paint some trees with the figures of men, often the exact number of their party, and if they go by Water, they delineate a Canoe, when they make an atchievement, they mark the Handle of their Tomahawks with human figures to signify prisoners, bodies without heads to express scalps. The figures which they affix to/ Deeds, have led some to imagine that they had Characters or an Alphabet. The case is this, every Nation is divided into a Certain number of Tribes [clans], of which some have 3. as the Turtle, Bear

⁴ Although the stone was the Oneida national symbol, in the League a tree trunk denominated that tribe.

& Wolf, to wch others add the Snake [ecl?], Deer, &ca, each of These Tribes [clans] form a little Community within the Nation, and as the Nation has its peculiar Symbol so each Tribe [clan] has the peculiar Badge from whence it is denominated, and a Sachem of each Tribe [clan] being a necessary party to a fair Conveyance such Sachim affixes the mark of the Tribe [clan] thereto, wch is not that of a particular family (unless the whole Tribe [clan] is so deemed) but rather as the publick Seal of a Corporation. [Pp. 436-437.]⁵

* * *

As to the information wch . . . I formerly Transmitted to the Gov^r of N. York concerning the belt & 15 Bloody Sticks sent by the Mississagaes, The like is very Comon and the Ind^s use Sticks as well to Express the alliance of Castles as the number of Individuals in a party, These Sticks are generally ab^t 6 Inches in length & very slender & painted Red if the Subject is War but without any peculiarity as to Shape. Their belts are mostly black Wampum, painted red when they denote War they describe Castles sometimes upon them as square figures of White Wampum, & in Alliances Human figures holding a Chain of friendship, each figure represent^s a nation, an axe is also sometimes described wch is always an Emblem of War, the Taking it up is a Declaration . . . and the burying it a token of Peace, . . . [O'Callaghan, 1851, vol. 4, pp. 430-437.]

Thus Johnson equated the Chippewa use of red-painted message sticks with Iroquois practice, more commonly expressed in wampum belts, on which the red ceremonial war paint likewise had a sinister significance. It might be reasoned that the more widespread message sticks are an older and more basic idea underlying the Iroquois wampums which attained prominence in colonial treaties. It is clear that the Iroquois understood and on occasion used sticks for more common purposes than they employed wampums, but in either case the mnemonic pictographs were essentially the same.

Our previous reference to the notched message stick among the modern Iroquois is confirmed by Beauchamp (1905, p. 169) who found that Father Bruyas (1862, p. 56) had noted a Mohawk radical (*Gahwengare*) for the custom of issuing invitation sticks to feasts in the seventeenth century. An Onondaga woman of Beauchamp's acquaintance kept a day count by notching a long stick and using a cross for Sunday after the death of a son. When visitors were welcomed at Onondaga in his day a solemn occasion was observed by sending out a runner to meet and record their numbers on a stick which he turned in to the council. The Tuscaroras of Lewiston, N. Y., have a similar manner of recording votes when the matrons report their selection of a chief to the council.

We can sustain what Johnson wrote by modern usage or by appealing to early writers. It was the Huron custom, for example, to

⁵ Possibly Johnson saw the distinction between clan and lineage.

hand an ambassador whom they desired to hear “. . . a little bundle of straws, a foot long, which serve as counters, to supply the place of numbers and to aid the memory of the assistants, distributing in different lots these straws, according to the diversity of things which they recount.” (Jesuit Relation, 1646, in Beauchamp, 1905, p. 170.) DeVries (1857, p. 118) noted a similar use of sticks among the Indians of Manhattan and Long Island, 1643. And Father Louis Hennepin was present at a council held January 1-2, 1679, in the great village of the Senecas, meeting in the cabin of the principal chief Tagarondies for whom the village was named. He writes:

The Next Day the Iroquese answered our Discourse and Presents Article by Article, having laid upon the Ground several little peices of Wood, to put them in mind of what had been said the Day before in the Council; their Speaker, or President, held in his hand one of the Pieces of Wood, and when he had answered one Article of our Proposal, he laid it down with some Presents of black and white Porcelain, which they use to string upon the smallest Sinews of Beasts; and then took up another Piece of Wood; and so of all the rest, till he had fully answer'd our Speech, of which those Pieces of Wood, and our Presents put them in mind. When his Discourse was ended, the oldest man of the Assembly cry'd aloud for three times, *Niaoua* [Niya-wenh']; that is to say, It is well, I thank thee; which was repeated with full voice and in a tuneful manner by all the other Senators. [Thwaites, 1903, vol. 1, pp. 85-86.]

On arrival at the last great treaty which the Six Nations held with the United States at Canandaigua, N. Y., during the autumn of 1794, the Senecas registered the size of their delegation by having each chief deliver “. . . a bundle of sticks, answerable to the number of persons, men, women, and children under his command. . . .” (Savery, 1844, p. 64.)

Other than the frequent mention of sticks, belts, and strings of wampum, none of the early writers on the Iroquois reports mnemonic pictographs for the Condolence Council. The painted war records, however, suggest pictographs painted on bark which were in general use among the Central Algonquians. The Ojibwa pictorialized on birch-bark scrolls the traditional history of the Medicine Society, the order of ritual, and mnemonics for individual songs (Hoffman, 1891). On the Plains the medium became the buffalo robe. But Johnson's reference to “. . . 15 Bloody Sticks sent by the Mississagaes . . .” brings us back to pictographs painted or engraved on sticks of hardwood. Hoffman illustrated one of these so-called “medicine sticks” (p. 289, pl. 21) but thought that their form was copied from objects of European origin. Erminie Voegelin, in discussing certain parallels to Delaware *Walam Olum* (1939, p. 29), found these sticks

only among Chippewa, Kickapoo, and Delaware. To this list we can now add Montagnais, Shawnee, and Cayuga.

In commenting on how Algonquians generally preserved myths, chronicles, memory of events, and speeches by means of marked sticks, Brinton (1885, p. 59) noted that the Jesuits in Canada as early as 1646 used them for teaching prayers to converts and for remembering sermons. The Relation of 1645-46 of the Holy Cross Mission at Tadoussac (Jesuit Relations, vol. 29, pp. 123 ff.), which served three bands of the Montagnais and possibly the Eastern Cree, makes it clear that such were devised by the missionaries after the Indian manner. It reads:

Some carried little sticks, in order to remember their sins; others marked them on the beads of their Rosaries; others wrote them, *after their fashion*, on small pieces of the bark of trees; . . . [Pp. 131-133.]

* * *

The Father, . . . , left them five books or five chapters of a book, *composed after their manner*; these books were . . . five sticks variously fashioned, in which they are to read what the Father . . . inculcated upon them. [P. 139.]

The Relation continues: "The first is a black stick, which is to remind them of horror . . . former superstitions . . ."; a second bore ". . . white . . . marks . . . [for daily] devotions and prayers . . ."; a third was red for Sunday and feasts; the fourth was the book of punishment; and the fifth carried ". . . various marks . . . [reminding them] how to behave in dearth and plenty . . ." (P. 141.)

Such was the basis of the famous "talking books" of the Cree and Chippewa, since these tally sticks were called *massinahigan*,⁶ "a piece of wood marked with fire." Their early use by the Jesuits, nevertheless, may account for the catechistic approach of Indian prophets later on. We are not concerned with how the Chippewa used fire-marked wooden tablets, the details being accessible (Kohl, 1860, p. 143; Schoolcraft, 1845, pp. 27-33; Hoffman, 1891, p. 289), but will repeat certain other accounts for the Delaware, Kickapoo, and Shawnee, which bear a certain relationship to the Cayuga specimen that is before us.

It is alleged in the "Pontiac manuscript" (Parkman, 1851, p. 183) that a prophet appeared among the Delaware then living on the Muskingum in 1762. The prophet, on the authority of Pontiac, the great Ottawa war leader, had received from the Great Spirit "A prayer, embodying the substance of all that he heard. . . . It was

⁶ *malackhickan* (Delaware) (Brinton). For a discussion of Ojibwa-Ottawa pictography and etymology of the word, see Voegelin, 1942.

cut in hieroglyphics upon a wooden stick, after the custom of his people, and he was directed to send copies of it to all the Indian villages." None of the Delaware prophet's prayer sticks has been preserved to our knowledge.

The United States National Museum, however, has an engraved prayer stick that has been ascribed to the Kickapoo prophet, Kanakuk, and Catlin made a portrait of Onshawkie holding a similar stick; both of these have been published by Mooney (1896, pp. 670, 698), and they are discussed by Voegelin. On the use of these sticks which the Kickapoo prophet carved and sold to his followers, 1827-34, there is an eyewitness account by the Rev. Isaac McCoy, which appeared in his scarce "History of Baptist Indian Missions" (New York, 1840), made when the prophet was living on the Illinois River:

Kenekuk, the Prophet, claimed the honor of being the founder of his own sect . . . His adherents were about four hundred souls, about half of whom were Potawatomes. He professed to receive all that he taught immediately from the Great Spirit . . . Congregational worship was performed among them, and the exercises lasted from one to three hours. They heard speeches from the Prophet, and all united in articulating a kind of prayer, expressed in broken sentences often repeated, in a monotonous sing-song tune, equalling in length about two measures of a common psalm tune. All in unison engaged in this; and, in order to preserve harmony in words, each held in his or her hand a small board, about an inch and a half broad and about ten inches long, upon which was engraved arbitrary characters, which they followed up with their finger until the last character . . . These characters were 5 in number. The first represented the heart; the second, the heart, affections, and flesh; the third, the life; the fourth, names; the fifth, kindred.

Considerable detail follows on how the characters were gone over several times (Foreman, 1946, pp. 213-214). Other accounts indicate that Kanakuk's prayer sticks were followed with the index finger from top to bottom.

Another sacred slab attributed to the Shawnee prophet, Tenskawatawa, who flourished somewhat earlier, and whom Catlin painted holding his "medicine fire" in 1831, was collected among the Winnebago about 1922 by Milford G. Chandler and now reposes at the Cranbrook Institute of Science; it has been described (Galloway, 1943). Identical sticks of the Shawnee prophet are in the Milwaukee Public Museum and in the Blackhawk Museum (R. T. Hatt, personal communication).

In general, these engraved and painted sticks that we have been discussing are mnemonic devices to aid in recounting tribal history, or they carry formulae for some sequence of phenomena that must be preserved unaltered: lists of dates, events, names, places, significant

stations in prayers, songs, order of ceremony, mythology, or treaties. There is a considerable literature on Iroquois wampum belts with attendant explanation of mnemonic pictographs that they preserve. But the bark records and the painted posts on which war leaders delineated their achievements have vanished. Only the colonial documents bear the signatures of Iroquois chiefs, which usually take the form of outline drawings of clan eponyms—wolf, bear, turtle, snipe, beaver, eel; sometimes objects—war club, tree, circles connected by a line to signify ground nut (*Apios tuberosa* Moench.), the mark of the Potato, or possibly, the Ball clan. The living descendants of the Five Nations can contribute little to our understanding of ancient pictographs (Hewitt and Fenton, 1945), although the following description of the Condolence cane sheds some light on how the ancient law-givers kept a record of their councils.

THE CANE OF ANDREW SPRAGG

A document out of the leaves of a primitive council record comes down to us in the form of a cane bearing pegs and corresponding pictographs to denominate the founders of the Iroquois League. This is a primitive roster of the chiefs of the Five Nations—Mohawk, Oneida, Onondaga, Cayuga, and Seneca tribes—such as were the village chiefs whom Deganawi'dah and Hiawatha persuaded to accept the Great Peace. The beginnings of the Confederacy are related in the Deganawi'dah legend which states unequivocally that the roll call of the founders, the proportional number of representatives for each tribe, how the chiefships are related to each other as individual offices in tribal councils, and the relation of tribes to each other in the council of the League must be maintained in the original order as it was decreed by the founders. In all likelihood the number of titles has increased and the order of enumeration has changed during the centuries that have elapsed since the village chiefs of the Mohawk, Oneida, Onondaga, Cayuga, and Seneca tribes formed the League, which they likened to an extended house, *Ganonh'syoni*, before the close of the sixteenth century. Whatever new titles were added to the original roster and however succeeding chanters of the roll call have changed the order of reciting the names, the cane of Andrew Spragg, the famed Cayuga ritual singer, is a true tally of the names of the Five Nations chiefs who, following the American Revolution, as Empire Loyalists, reconstituted the League from its shattered remnants after coming to Canada and settling on the Grand River. At least the cane, as we shall see, agrees substantially with Morgan's

1849 list of titles from the Tonawanda Seneca reservation east of Buffalo, a manuscript roster in the orthography of the Anglican missionaries at Grand River, the Canienga Book of the Condoling Council (Hale, 1883), and various lists of League chiefs collected at Six Nations Reserve by Hewitt, Goldenweiser, and the writer.

THE MAN

Not much is known about Andrew Spragg, or "Sprag," as it is spelled on the cane; "Spragge" on the Agency rolls. He is pictured among a group of chiefs and warriors who visited Toronto, June 1897, on the occasion of a visit by the Governor General. He appears to be middle-aged, he wears his hair long, and has a moustache. He must have been active because in another picture he is postured in War dance. Like several of his colleagues he wears a circlet of turkey feathers, and Spragg alone has a shoulder sash. Quite unmistakably they are having a good time. (Chadwick, 1897, frontispiece and opposite page 80.) He was an informant to several ethnologists before World War I. Frachtenberg (1913) employed "Andrew Sprague, a Cayuga, who in his early youth had been adopted by the Tutelo tribe," as an interpreter, and obtained from him some information on Tutelo history and ritualism. Sapir (1913) credits Sprague with having heard Tutelo spoken during his childhood, in reporting on a small Tutelo vocabulary collected from him in August 1911. But neither F. W. Waugh, A. A. Goldenweiser, nor J. N. B. Hewitt seem to have worked with him.⁷ Visiting Tutelo descendants on the Six Nations Reserve in later years, Speck (1942) found the memory of him quite clear.

But it was Yankee Spring, a Tonawanda Seneca, who first told me about Andrew Spragg. Yankee had served a term of 5 or 6 years as secretary of the council of the Tonawanda band of Senecas, and during his office he pondered: Why was he not a chief, why were others of no apparent ability installed in office? He had been caught in the dilemma of changing customs. The new elective system was theoretically based on achievement and opposed the old system of life chiefs appointed by the matrons of certain clans, so that the band was torn between the new method of election and the old way based on family lines.

Yankee inquired of the old men of Tonawanda, the quandary took him to Onondaga (Syracuse, N. Y.), and ultimately to Canada. On

⁷ Waugh, F. W. (1916), Mss. on Folk-lore, medicines, and material culture; Goldenweiser, A. A., Reports to Anthropological Division, Dep. Mines, Geol. Surv., Ottawa, and Mss.; Hewitt, J. N. B., Ann. Reps. to the Chief, Bur. Amer. Ethnol., and Mss.

his Canadian visit Yankee lived a winter in the home of Andrew Spragg, a member of the Lower Cayuga band on the Six Nations Reserve. During the long winter nights, Andrew, who was by then a famed Cayuga ritualist, coached the Seneca student on matters relating to the League: its beginning, how chiefs were apportioned by tribes, ranking and position of the Five Nations in council, the order of business, and how the founders proceeded to make laws. While instructing his student Spragg made continual reference to a cane, which Yankee remembered and described to me in detail during interviews in 1934. Among other things, Yankee recalled vividly the spacing of the Five Nations on the cane, from Mohawks at its head to Senecas at its tip, segregation of the chiefs by classes, and the use of pegs to denominate individual titles. Yankee asserted, however, that the cane was surmounted by an eagle carved of wood, which symbolized the totemite of the Five Nations, and served as a handle for the singer who carried it when reciting the roll call of chiefs in the ritual of Condolence.

A year elapsed. We spent a day, August 3, 1935, at the Six Nations Reserve searching for the cane. Andrew Spragg was dead, and the Condolence cane which Yankee Spring had seen in his possession, we were told, was in the custody of Chief John Davey (Onondaga), fire-keeper of the Six Nations council. Cayuga Chief Jim Crawford, since deceased, promised to write when the cane could be seen. Neither Yankee Spring nor I ever heard from him. Spragg's son had moved to the city, Chief Davey was not at home, and none of the chiefs whom we interviewed could affirm that he had seen the cane since Spragg had gone the long trail.

Andrew Spragg spent his life with the Lower Cayuga band of the Six Nations of Grand River. We do not know when he was born. According to the records of the Six Nations Indian Office in Brantford, Canada, Andrew Spragge, as his name appears on the roll of the Lower Cayuga band, was aged 38 in 1902 (therefore born 1864); and the same entry is marked "D 1921," but the year 1921 is crossed out (Census Record of Lower Cayuga Tribe, p. 164, from "Old Book," p. 337). Andrew Spragge is credited with a son, "A. Averson Spraggie, B. 1888/D. 1937." The latter is Patterson Spragge, whose son Raymond was born June 23, 1937, presumably to his wife, Louisa Williams. The so-called Old Book (p. 337) contains a contradictory entry, as follows:

1893 Andrew Sprag	26 (B. 1867)
Betsy	17 (His wife, p. 177)
Martha	
Averson	1894.

According to the latter record Andrew Spragg was born in 1867, and there is a discrepancy of 6 years in Averson's birth date.

The Current Census of the Cayuga Tribe (p. 487) bears entry "No. 146 B. 1888/ Spraggie, A. Averson/ D. June 8, 1937/ w. Lavina Williams." These are substantially the same dates as given on his grave slab in the cemetery at Lower Cayuga Longhouse. At the Indian Office A. Averson is believed to be the same person as Patterson.⁸

To cross-check we looked up Andrew's wife Betsy (Old Book, p. 177).

Betsy 29 1903 To self 177
Martha
Averson
Rosa V. Bill
Lavina Williams

The last, at least, appears above as wife of Averson.

From this we may conclude that Andrew Spragg was born about 1865 and died about 1921. He married a woman named Betsy, somewhat younger than himself, and they had a daughter Martha and a son Averson. The latter, who is also known as Patterson, was born between 1888 and 1894, depending on who kept the book, and he had a son Raymond born in 1927; the father died in 1937. Averson's relation to Rosa V. Bill and Lavina (or Louisa) Williams is not clear, but one was his wife or both were.

Andrew Spragg is remembered by his neighbors. Elliott Moses (Delaware) as a lad of 18 worked out on the same farm with Spragg, whom he remembers as

a typical raw-boned Indian of about six feet. He was said to be the last full-blood on the reserve. One day at table Andrew remarked that he had taken his son out of Mohawk Institute (a boarding school for Six Nations Indians at Brantford) because, as Andrew alleged, the boy was only learning to swear.

Andrew's English became somewhat inverted in the telling, which amused those present and caused Mr. Moses to remember the incident. That Spragg spoke English imperfectly assumes importance because it therefore appears unlikely that he read with sufficient facility to have been influenced by what he had read about Iroquois ceremonials. Yankee Spring had said that Andrew Spragg owned a copy of Morgan's "League."

⁸ I am very much indebted to Hilton M. Hill, for many years Clerk of the Indian Office and Interpreter, to whose friendship I was fortunate to succeed after the late J. N. B. Hewitt, for identifying the vital records on his Iroquois brethren; and Miss Henderson of the Indian Office recalled to mind Spragg's living descendants.

Patterson Spragg, the only son of Andrew, met an untimely end when he was trampled by a horse. He was buried at Lower Cayuga cemetery just west of the Longhouse, where we found a headboard still legible in October 1943: "Patterson Sprague, died June 9th, 50 year old 1937" (pl. 1, fig. 1). The headboards of a nearby group of graves are no longer decipherable, and we did not succeed in locating the grave of Andrew Spragg, although it was thought to be nearby.

A log house that Andrew Spragg occupied for many years still stands at the crossroad known as Sandy's Corners, which is the first intersection in the road leading from Willow Grove on Highway No. 6 across the east boundary line of the reserve toward Ohsweken, the seat of the Six Nations Council (pl. 1, fig. 2).

Councilor George Buck now occupies the house of the late Cayuga chief, Abram Charles, having married Chief Charles' daughter, and they live but a short distance from Sandy's Corners and the house of Andrew Spragg whom they remember. George Buck said:

His house at Sandy's Corners formerly stood near the bush, but later it was moved to its present position near the road.

Andrew was a great one to sing all kinds of songs. There was almost nothing that he could not sing. Unfortunately, no one learned his songs. Once he urged me to come spend the winter with him, saying that he would teach me his songs. I didn't go. But I remember the cane clearly. I saw it often at the house where I now live when my wife's father, Chief Abram Charles, was alive. I never learned the words to Hai Hai atahinó'geh (the eulogy for marching on the road). The song is easy but the words are hard.

Andrew died in 1921 or 1922 in the house of Fanny Bill (wife of Jake Fishcarrier). I know that because that is the house where I was brought up.

It seems that in his later years Andrew Spragg abandoned the house at Sandy's Corners and moved north to the next concession road to reside in the house now occupied by Fanny Bill (Mrs. Jake Fishcarrier), who was his wife's granddaughter; Fanny Bill's is the first house east of Lower Cayuga Longhouse; he was living there when he died. It was presumably during his residence at the latter place, a short step from Peter Atkins' Corners, now called Six Nations', that he relinquished the cane.

Neighbors along the road to Willow Grove where he resided for many years recall that Andrew Spragg was an enterprising character of considerable mechanical ingenuity. According to C. W. Monture,

Andrew was a great one to fix things. He had a steam thresher, in the days before separators with blowers, and it was driven by an upright engine. The whole rig was pulled by a heavy team. With this outfit he went from farm to farm threshing grain. Come fall, he pressed hay with a team. He was the first man here to attempt to devise a power press for his engine before the advent of tractors on the reserve.

Such anecdotes serve to illustrate that the man had an inventive turn of mind and some mechanical aptitude. Nevertheless, we do not think that he made the cane. Before taking up this matter, however, another anecdote relates to his threshing machine, and his prowess as a runner, which was remarkable even among the nation that produced Tom Longboat, famed Canadian marathoner. One rainy spring afternoon in 1945 the conversation in the village store at Ohsweken turned to track and field sports, a perennial interest among the Six Nations. Without my making any suggestion of an interest in the man, one of the villagers, a stalwart farmer who had been rained in from drilling grain, related the following tale about Andrew Spragg:

The Lower Cayugas had a great runner before Tom Longboat's time. He was a fellow named Andrew Spragg who lived down at Sandy's Corner, the first one this side of Willow Grove. He used to run a steam thresher, and one day they were threshing out oats down at Monture's when the separator broke down. The crew thought they were through for the day, but Andrew said to stand by while he ran to Caledonia (not less than 5 miles) for a part. When he reached the implement dealer's in Caledonia he was told that the part was not in stock and that one could not be had this side of Hamilton. Andrew asked them to call the dealer in Hamilton, the part was there, and the dealer was informed that Andrew would come after it afoot. There was no transportation then from Caledonia to the city. To the Massey Harris agent's amazement, in scarcely more than an hour an Indian who said he was Andrew Spragg presented himself at the counter, the broken part in his hand. "How did you get here so fast?" said the agent. "On the road," was all that the Cayuga volunteered. "Why, it's at least 12 miles from Caledonia to the rim of the Mountain!" (the high escarpment behind Hamilton which lies at the level of Lake Ontario). They collected a bet of 10 dollars in the store, to say that he could not run back to Caledonia in an hour. He was to telephone when he reached Caledonia. They had lost a lot of time threshing, Andrew thought, and he would have to pay for the men, as well as the part. Andrew needed that 10 dollars. He passed through the village of Caledonia in less than the allotted time. They were watching for him in Caledonia because Hamilton had telephoned. The Caledonia dealer called the Hamilton agent who agreed to forward the money. Andrew kept on running until he arrived back where they fixed the thresher and went back to work, having lost less than 3 hours.

That's a world's record in any man's country!

It is when one considers that 10 miles per hour is excellent time on the road, and the great Nurmi ran 11.94 miles in an hour.

Because the above seemed wholly incredible, and in hopes of learning how the tale might be elaborated in a second telling, I wrote to Mrs. Sadie Jamieson in whose Ohsweken store the liar's bench flourishes as a going institution. Sadie put the question to several customers, and finally wrote on April 10, 1947, that she had a second version from Jerome Duncan, who had told it to my first informant.

"It sure is a liar's bench problem," she comments, ". . . whoever told that one would get the chairman's seat."

Andrew Sprague was a thresher and when threshing for a certain farmer near Peter Atkin's corner, some small part of the machine was broken. He told his men that he had to go to Hamilton to get it, and since there was no transportation, he said he would run.

So he started out. Going through Caledonia, he stopped at a machine dealer's, called Holsteins, and there he found the part he wanted. He ran all the way back and was back in $\frac{3}{4}$ hour and inside of an hour they were threshing again. He never told the men that he never went to Hamilton at all.

Some man said to him "I'll just bet you \$10.00 that you can't run to Hamilton and back in the same time." So he took him up on it.

They told him they would wait at Atkin's store and he was to phone when he got to Hamilton.

He started out running the second time and only went as far as Caledonia again and got the same part again. Just before he left Caledonia he phoned Atkin's store and made them believe he called from Hamilton. He ran all the way back and made it in $\frac{3}{4}$ hour. Andrew Sprague won the \$10.00.

The distance from Caledonia to Hamilton is 14 miles, and 5 miles from Caledonia to where he was working.

Although it is apparent that Andrew Spragg was a man of no little accomplishment he was never a Cayuga chief. He belonged to the Lower Cayuga Longhouse, where he faithfully attended the religious exercises of the Handsome Lake Religion, and he mastered several of the rituals. His fame as a singer is equally confirmed by leaders of the Onondaga Longhouse. "Andrew was smart (agile) and the Lower Cayugas always had him to sing *Hai Hai* on the road because he knew the words (of the eulogy) and he was a good walker." (S. Gibson.)

This statement was corroborated by Hilton M. Hill (Seneca-Tuscarora) who was for many years Chief Clerk of the Indian Office in Brantford. The Cayuga chiefs depended upon Andrew Spragg's memory, his voice, and his legs to carry the roll call over the road from Lower Cayuga Longhouse to Onondaga, a distance of 2 miles. Some of the Cayuga chiefs were too advanced in years to lead the procession; the late Abram Charles was a noted ritualist, but he was deaf and never sang on the road. "Andrew Spragg was the only one who always used the cane."

The Onondaga chiefs of the Six Nations Reserve regarded Andrew Spragg as an independent fellow. He not only carried a unique cane that came to be associated with the Lower Cayugas (the Onondagas manage to perform the ritual when installing Cayuga chiefs without

reference to such mnemonic aids); but he had his own ideas about the ritual. Spragg had a book.⁹

The last time he came up to our [Onondaga] longhouse to install a chief, he had altered the roll call. There are names for 50 chiefs in the council of the League. There are also 50 pegs on the Condolence cane. Andrew had cut off a peg, the last one on the Onondaga roll, leaving but 49. Andrew claimed, as they have recently claimed at Syracuse [Onondaga Reservation], that the last chief serves double duty, having both the titles *Ho's'ähha-'hwih* and *Sganarwa-'dih*, that the last chief is of opposite sides (moieties) to himself, holding two offices. We claim there are 50 chiefs. (D. Thomas.)¹⁰

Unless Spragg had changed his mind about the number of federal chief titles, he would not have made the cane with 50 pegs in the first place. The fact that he is alleged to have cut off a peg points to an earlier maker. And there is some opinion in the community bearing on earlier holders. Cayuga Chief Alex General could not recollect in 1945 whom in the generation before Andrew Spragg he had heard mentioned by Indian name as having made the cane. Chief General does not think the cane is old. Some years previously at a Condolence Council rehearsal the late Oneida Chief Jacob Isaac of Sour Springs (Upper Cayuga) talked of the cane that Andrew Spragg had and spoke the name of the man who made it before Andrew Spragg got hold of it. My informant had forgotten the name since hearing it.

To Chief General it seems likely that the cane came to Andrew Spragg in a Ten Days' Feast, which the mourners and their brother clans give to the cousin clans who conducted the funeral. "That is the rule."

Many times since the coming of the Cayugas to settle here on the Grand River the Condolence ceremony was nearly lost. Only a few in a generation

⁹ Chief Crawford had told Yankee Spring and the writer in 1935 that Spragg had a copy of Morgan's "League of the Iroquois," a fact confirmed by Yankee Spring and by Milford G. Chandler who collected the cane. We do not know that Spragg was literate.

¹⁰ J. N. B. Hewitt had come to the same opinion as Andrew Spragg. I have not discovered that Hewitt had employed Spragg as an informant. In a conversation held in his office in October 1934, Hewitt stated that originally when the League was established, one recalcitrant Onondaga war chief refused to relinquish the privilege of going on the war path, but in order that he might continue to go to war he took both a federal chief's title and retained a warrior's name. Accordingly, he is represented as having his body divided in twain: in his right hand he holds the war club, and his left side stands for peace; he is at once *ho'skë'ggeh'de'*, "warrior," and *hoyaa'neh*, "law giver." Hewitt has documented this statement in a number of reports (37th Ann. Rep. Bur. Amer. Ethnol., p. 12, 1923; 41st Ann. Rep. Bur. Amer. Ethnol., p. 10, 1928; Introduction to Iroquoian Cosmology—part II, 43d Ann. Rep. Bur. Amer. Ethnol., p. 463, 1928).

would know it. Then it revived. That is why they made something like the cane to remind them. Also, the songs may be sung only at stated times, in spring and fall, which are the only times when it may be rehearsed . . .

A MUSEUM SPECIMEN

The mystery attending the fate of the Condolence cane of Andrew Spragg solved itself suddenly and unexpectedly in early 1943, when Dr. Robert T. Hatt, Director of the Cranbrook Institute of Science, asked the writer to describe a unique specimen of a cane or stick in their collections, which Dr. F. G. Speck (University of Pennsylvania) and Dr. Arthur C. Parker (Rochester Museum) independently had identified as a roll-call tally of chiefs in the Iroquois Confederacy. The stick had come to the museum in a collection obtained from Milford G. Chandler, a noted collector of ethnological materials among the Indian tribes of the Great Lakes area.

Mr. Chandler first heard of the cane on a collecting trip to the Grand River in about 1917 or 1918. It was then in the possession of Andrew Spragg who, at that time, refused to sell. About 2 years later, however, after the midwinter ceremony in February, the stick was acquired. With the stick was a manuscript which, according to Spragg, contained a list of chiefs' titles very similar to the list found in Morgan's "League of the Iroquois" (1851). The manuscript contained a sentence about each peg on the cane; it was formerly kept bound to the stick but was subsequently lost.

Sprague assured me that this was the original roll call stick of the League of the Iroquois and had been handed down to him. He said that he was the one at that time to check the roll call. He would press his thumb against the peg representing a particular chief and call his name. There were two pegs cut off level representing men who were not true officers but who were doorkeepers.

* * *

Sprague was a man of medium height, angular and slender in build. He lived in a dilapidated house within walking distance of Six Nations Post Office and near the Cayuga Longhouse. Atkins, at that time Postmaster at Six Nations, acted as guide and interpreter for me.¹¹

In recalling these circumstances Mr. Chandler remembered that he stayed with Peter Atkins, Postmaster at Six Nations Post Office, and that Andrew Spragg lived nearby, next to Lower Cayuga Longhouse, as George Buck and others have confirmed. It was his impression that the cane was used in the council meetings to call the

¹¹ From a statement dictated by Milford G. Chandler regarding the Iroquois Condolence cane now owned by the Cranbrook Institute of Science, dated May 7, 1945. Personal interview, October 1944.

roll of chiefs present, one for each of the pegs opposite which is a representation of some characteristic in the chief's title. He does not seem to have understood its use in the Condolence Council ritual. To enrich the collector's understanding of the ceremonial setting, nevertheless, the old Cayuga singer referred him to a copy of Morgan's "League . . ." with its list of chiefs. Clearly this was the cane that we were seeking.

Observe that Spragg thought the cane coeval with the League, that it had been handed down to him, and it is implied that two pegs cut off reflect some controversy on relative status of doorkeepers to other federal chiefs.

The name "A SPRAG" is rudely carved on the back of the stick near the handle in a somewhat different style from the drawings. The question that this poses is not who had title to the cane. Rather, our interest is to illustrate how an item of Indian personal property, through long association with public ritual, came to be regarded as tribal property, or, conversely, how public property may become personalized. To be sure, certain properties such as wampum belts belonged to the confederate council and they were entrusted to appointed keepers among the chiefs. Such properties "belong to the Nation." They are state properties, not exactly in the public domain. Similarly each longhouse or ceremonial center has entrusted among its membership certain paraphernalia which is used at stated festivals; this is band or tribal property; it too belongs to the Nation. Nevertheless, one cannot readily distinguish between property that the community owns and other similar things which individuals possess, and sometimes own outright. Thus, a longhouse community will harbor a bag of Husk Faces, corn-husk masks for the Midwinter Festival and for family feasts to honor certain agricultural spirits that have curing powers, but also members of that community will personally own such items that they have inherited or that have been made for them in response to dreams, thereby becoming personal guardians; and these they may lend or convey, within certain limitations, as they will.

The Iroquois draw the property line around the person in a way that does not circumscribe as many kinds of property as among us. Rather the individual participates in a wider sphere of property sharing than we can conceive. He participates in tribal property, in band property, that of his maternal family, his fireside household, besides his own personal property. As an individual he owns outright the tools and implements that he employs in his daily life, his weapons, but physical belongings apart from these, such as a boat, he will lend

readily to friends and neighbors; his rights to certain kinds of knowledge including medicinal formulae and prayers associated with talismen or personal guardians are private and inviolate. Membership in a maternal family confers upon the individual copyright privileges during his lifetime to certain songs, a personal name, and possibly a chiefship title which also belongs to the clan, to the tribe, and to the League. Knowledge of a public ritual, however, is neither personal nor family property, although but few individuals acquire such erudition. Likewise the mnemonic aids that an individual employs to remind himself how the ritual proceeds belong to the group as they have a public function; and other members of his band and tribe come to regard these properties as belonging with the group's ritual paraphernalia. But the individual to whom the particular piece of paraphernalia is entrusted and who employs it in the public ceremony may come to feel a proprietary right to it that others do not share or acknowledge. This, I think, is the case of Andrew Spragg and the mnemonic cane that he had carried during innumerable journeys on the road from Lower Cayuga to Onondaga Longhouse while chanting the Eulogy to the Founders of the League. Andrew felt entitled to carve his name on the stick, which his contemporaries possibly and his survivors certainly considered as belonging to the Cayuga Nation.

The immediate reaction of an Upper Cayuga chief, to whom we showed a diagram of the cane, was: "It never should have left the reserve because it was [Cayuga] Nation property." The same chief thought that the cane antedated Andrew Spragg and that it had been entrusted to Spragg by some former keeper to use in the Condolence Council. The late Simeon Gibson,¹² himself heir to a Cayuga chiefship, was less positive that the cane belonged to the tribe. He knew that the Lower Cayugas had had this cane, and that only that band had one. That the Onondagas of the Three Brothers side (Mohawk-Onondaga-Seneca) never used this cane all informants agreed; its use was confined to the Four Brothers (Oneida-Cayuga-Tuscarora-Tutelo). The Three Brothers manage without one. Moreover, Gibson, whose family was of the Lower Cayuga band, discredited the statement of the Upper Cayuga chief by saying:

The Lower Cayugas have been for years the only Cayugas who could sing at the installation of chiefs on the Three Brothers side, for until recently there have been no singers of the ritual at the Sour Springs (Upper) Cayuga Longhouse.

¹² For an account of the man and the writer's field work on the Six Nations Reserve to that date, see "Simeon Gibson: Iroquois Informant, 1889-1943" (Fenton, 1944).

Until my spring field trip of 1945,¹³ only Andrew Spragg had been identified with the cane. No one could say who had made and inscribed the cane, only that it had been among the Lower Cayuga band for a long time. Andrew Spragg was the last singer seen to carry it "on the road" to install chiefs at Onondaga. The hereditary chiefs had been under attack by the Indian Department, and we are reminded that in the Indian Act of 1924 Canada abolished the confederate council on the Grand River. It was during this time of trouble that Spragg was growing old, and since the old way was failing, he let the cane go.

But despite the Indian Act, the system of life chiefs goes on, albeit unofficially, to provide the leadership for the longhouse communities on the Six Nations Reserve. In order that the men to whom the people now look in confidence might benefit from knowing how their predecessors remembered the roll call of the founders of the League the writer carried an enlarged line drawing of both sides of the cane to show to informants. The present ritual holders desired so many copies that the Cranbrook Institute had the original drawings blueprinted. Two of my Iroquois friends have since reproduced the original.

According to John Smoke (Cayuga), an old man of the Lower Cayuga band whom Howard Skye (Cayuga) consults on League matters, and who is known by the Indian name T'awenén'dró', or properly, T'awéne's, "Word sinking in deep snow, or mud," the cane of Andrew Spragg was made by Gánawado, "Lime floating" (from onawada, "lime"-, and -o, "floating on water"- as in a lime pit). Gánawado had the English name of Styres and was the grandfather of Edward Styres, a Cayuga man of between 30 and 40 years in this generation; the latter's father, Joe Styres, died at about 65 years in 1939 or 1940. Gánawado was father of Joe, who was born about 1880.

From Gánawado, the maker, the cane passed to Billy Wage, an Onondaga who lived among the Cayuga. From Billy Wage it went to A. Spragg. No one knew what became of it after that.

Gánawado was a *Hai Hai* singer and used the cane in the Condolence ceremony.

Billy Wage was also a *Hai Hai* singer. He is the same ". . . Cayuga chief Wage (Hadwennine, 'His words are moving'), the high constable of the Reserve who is commonly known as Sheriff Wage . . .," of whom Hale (1895, p. 51) wrote in his journal of July

¹³ 62d Ann. Rep. Bur. Amer. Ethnol., pp. 3-4, 1946.

1883 and observed leading the delegation of the younger nations to the woods-edge fire at Onondaga. He had a suitable name for a *Hai Hai* singer who carries the ritual on the road. "While we were conversing, the sound of a measured chant was heard in the distance. All eyes were turned on the neighboring woods, from which was presently seen to issue the portly form of the Cayuga chief Wage . . .," etc.—Howard Skye equated the two from Hale's description.

While this gives us a base line for dating Billy Wage's performance of the role of *Hai Hai* singer, Hale did not mention a cane at this point in the ceremony observed, but when they got inside the Onondaga Longhouse, he noted that the Eulogy singer, the "elderly" Cayuga Chief Jacob Silversmith (Teyotherehkonh, "Doubly Cold") was ". . . bearing in his hand a staff, with which he seemed to time his steady walk." (P. 54.) We are without further details.

Our information states further that the cane did not belong to Andrew Spragg; "it belonged to the Cayugas. Gánawado made it for the Cayugas only. According to John Smoke, when Andrew Spragg got hold of the cane, he claimed it."

Such is the history of the specimen.

MATERIAL DESCRIPTION

Shape and general appearance.—With its bent handle attached, the Condolence cane bears a superficial resemblance to a dress sword (pl. 2). This was how one of my informants described it to me. The handle, at a second glance, might be mistaken for a discarded umbrella handle that, as a substitute for some earlier handle, had been attached from its side to the stick, like the hand guard of a sword, instead of by its axis, like the handle of an umbrella. In all probability, this is the original handle despite Yankee Spring's theory that an eagle perched on the staff. Viewed sideways, the handle conforms to the shape of the bows or crooks on hickory canes by Iroquois craftsmen. In fact, the handle could be reproduced by cutting the crook from the shaft of an Iroquois old man's cane. The handle appears to be made of white hickory.

When the cane was accessioned at the Cranbrook Institute, the handle was at first removed, since it was thought to be a later addition or substitute for some earlier handle. The handle has since been restored. Three informants who saw the profile drawing of the stick without the handle asserted that it was once provided with a handle like a sword guard. All these informants had seen the stick used in the ceremony at Six Nations Reserve but none mentioned that the handle was formerly an eagle head, as Yankee Spring had said.

Material and dimensions.—The stick itself is of sugar maple.¹⁴ It has an over-all length of 890 mm. Its greatest breadth midway is 37 mm.; its greatest thickness 15 mm. Tapering at the ends to an oval and flatter at the midsection, the general appearance of the stick suggests an Iroquois bow stave.

Panels or sections of pegs.—The lateral edges of one side are sectioned off into alternate panels in nice proportion to over-all length, three on the right, and two between them on the left. The panels are cut into the edge of the cane on a slant to form a standing bevel with the edge; the width of each bevel face is 10 mm., and the bevel makes a 45-degree angle with the top and sides. From the top of the cane the beveled panels measure 110, 118, 165, 125, and 110 mm., respectively. The panels have been drilled for seating wooden pegs with flat heads. The number of pegs per panel is apportioned unequally. From the top, the sequence of drill holes for pegs is: 9-9-14-10-8, totaling 50.

Some of the pegs are missing; one is cut off. Peg No. 32, being 14 in the third panel, has been cut off flush with the bevel. This is important, recalling the testimony of David Thomas (Onondaga) that Andrew Spragg insisted there were 13 Onondaga chiefs and had cut off a peg, because deleting the last Onondaga title would dispose of No. 14 in the third tribal panel.¹⁵ The following pegs are lost: 10, 12, 13, 15, 16, 17, 18, 29, 31, 44, 46, 47, 48.

Besides being grouped into five alternate panels, the pegs segregate themselves spatially within each panel in the following rhythmic patterns: 3-3-3, 3-3-3, 6(2-2-2)1-2-3-2, 2-3-3-2, 2-2-2-2. (Fig. 1.)

Pictographs.—Each peg, moreover, is illustrated by a pictograph. The pictograph stands opposite the peg so that when the cane is held alternately sideways the representations for each panel stand above the pegs, and the symbols can be read sequentially, first from right to left, then from left to right for the second panel, right to left again in the third, over to left to right in the fourth, until reaching the last panel when the stick is held away from the singer so that the characters may be read from near to far. Note that the first, third, and fifth panels, which are on the same edge, read from right to left, and the second and fourth panels, on the opposite edge, read from left to right. In all cases the sequence is from top to bottom of the stick.

¹⁴ Dr. Hatt submitted the specimen to Prof. Dow V. Baxter, School of Forestry, University of Michigan. Hatt, R. T., personal communication, June 16, 1945.

¹⁵ Another peg was cut off, according to the collector, Mr. Chandler, but, if true, that peg has been lost. (Hatt, R. T., personal communication, April 14, 1945).

	CRANBROOK CAYUGA CANE <i>a</i>	CAYUGA CANE (S.G.) 1940 AND CHARLES NOTEBOOK, 1916 <i>b</i>	J. H. G. 1940 (ADJUSTED) <i>c</i>	NEWHOUSE 1885 <i>d</i>	ONONDAGA REHEARSAL 1945 <i>e</i>
I	1	••	•••	•• 1	••
	2	••	•••	•• 2	I ••
	3	••	•••	•• 3	••
II	4	••	•••	4 ••	••
	5	••	(V) •••	5 ••	•• II
	6	••	•••	6 ••	••
III	7	••	•••	•• 7	••
	8	••	•••	•• 8	••
	9	••	•••	•• 9	•• III
	10	••	••	•• 10	••
	11	••	••	•• 11	••
IV	12	••	••	12 ••	••
	13	••	•••	13 ••	•• IV
	14	••	•••	14 ••	••
	15	••	••	15 ••	••
	16	••	••	16 ••	••
V	17	••	(II) •••	••	••
	18	••	•••	••	V ••
	19	••	•••	••	••
				SIX SONGS •• •• •• ••	
				15 STRINGS •••••	

FIG. 1.—The mnemonic systems of the Condolence cane, and for laying down corn at rehearsals. *a*, The Cranbrook Cayuga Condolence cane of A. Spragg; *b*, Cayuga cane of S. Gibson, 1940, and the Notebook of A. Charles, 1916; *c*, J. H. Gibson, 1940; *d*, Seth Newhouse, 1885; *e*, Onondaga rehearsal, 1945.

Less than half of the pictographs are representative designs; most of the characters are abstractions. A number of the representations relate to plants: a stalk and branches, branch and leaves, trunk and branch, a corn cob. Number 6 is a bird, 7 is an antler, a wolf appears at 25. Anthropomorphic designs, however, predominate; they are either of whole men, heads accentuating such parts as an eye, a double profile, an ear, profiles face to face, a flat head, a scalped head, etc. Over 25 are pure abstractions, or at least appear so until one learns what is intended. Therefore, pure symbols carry over half the burden, and together with the arrangement of pegs and panels comprise a true mnemonic.

The figures appear to have been drawn with a nail or hard pencil, with the sole exception of the tree opposite peg No. 4, which is definitely incised. Evidently the maker, or some keeper, never carried out an idea of carving all the figures after attempting the first four.

Reverse side.—The reverse side of the stick bears the name A SPRAG (fig. 2), followed by a series of symbols, which appear more clearly; and the cipher-shaped symbols are followed by representations of what may be intended for grass, brush overgrowing supine bodies lying over other matters that are represented by round objects, a dotted circle; and then come a parade of five human heads with horns (perhaps chiefs with antlers of office, evidently following the path to) a longhouse with two smokes, after which stands the erect bust of a man facing left toward what has preceded. The preceding symbols or characters are circles in units of one, three, five, and these are ranged from high (a single circle), middle (three ciphers on the level), to low (five ciphers with an appendage slanting downward to lower left on the last). Above the last are a line of five inverted c's, followed by three hache marks. Next come two parallel sets of linked ciphers and dots which slant from lower left to upper right. The first is surmounted by a dotted circle. The last is a line connecting two circles, passing between five smaller ciphers spaced three to the left and two to the right like the panels on the obverse of the stick. The last connected circle at the upper right of the second set has a pupil like an eye directed left.

Part of the next figure, possibly intended for a human heart or face, projects beneath the surface of a horizontal line into a triangle of three tiny circles; within the area of the figure above the line or surface are an open circle (possibly an eye) and another which appears to be directed along parallel rising broken lines to succeeding units.

The broken lines lead to a horizontal line on top of which are engraved short sets of vertical lines in all probability representing sod. Beneath the sod line is a supine figure lying on round objects, obviously in a grave. The succeeding unit is in character, but here the surface of the earth is overgrown with brush, and this time the body lying in its grave has a round object or cipher beneath its head as a pillow, and five short vertical marks support the body. The remaining figures require no further elaboration.

GENERAL SYMBOLISM

RECOGNITION BY THE IROQUOIS AND BY ANTHROPOLOGISTS

The specimen was submitted to several specialists on the Indians of northeastern North America. These anthropologists in turn supported their opinions by consulting native authorities among the surviving Iroquois. They are of one mind: the specimen is a roll-call stick, a cane to prop up the memory of the song leader who is appointed to chant the Eulogy to the Founders of the Iroquois League during the Condolence Council. The Iroquois know this rite as *Hai Hai*, a specific name for this feature that has become a general euphemism for the whole Condolence Council. Specifically in Onondaga of Six Nations Reserve it is *atahio'ge hai hai ne' gae·na'*, for which the word order is reversed in translation to read, "The song of eulogy for journeying on the path." In modern parlance this becomes "Hai hai for going on the road."

The stick was submitted first to the noted Iroquoianist, Dr. Arthur C. Parker, then Director of the Rochester Museum of Arts and Sciences, who examined the stick, made some tracings of it, and showed photographs of it to some Seneca chiefs at Tonawanda. Since the incorporation of the Seneca Nation on the Allegany and Cattaraugus reservations a century ago, Tonawanda is the last place in western New York where the system of life chiefs is preserved, and here are concentrated the eight titles that the Seneca tribe held in the council of the League. The present incumbents are the descendants of Morgan's informants. The present chiefs to whom Parker showed the photographs were able to interpret some of the names, but it puzzled them why some titles are represented as they are by the pictographs found on the stick.¹⁶ We would expect them to follow the enumeration of chiefs as given by Morgan, and they would be

¹⁶ Arthur C. Parker to Robert T. Hatt, February 3, 1943; Hatt, R. T., personal communication, February 5, 1943.

mainly concerned with the enumeration of their own number. If these were out of sequence by local standards, their wonderment does not amaze me since Iroquois personal names are subject to varying interpretation, and different versions gain acceptance in separated localities and in succeeding periods. The Seneca chiefs of Tonawanda do not exchange condolences with the Cayuga chiefs of Six Nations Reserve in Canada, but rather with the Onondaga chiefs of Syracuse, N. Y. Thus different variants of the ritual of condolence have developed on the American side and in Canada, and to some extent the interpretations of the titles have been localized, and the order of roll call near its end differs as certain pairs of titles are interpolated in New York and Canada.

The specimen was also submitted to Dr. Frank G. Speck, Professor of Anthropology in the University of Pennsylvania, whose wide field experience among eastern Indians includes a study of Cayuga ceremonialism. Speck recognized the cane immediately as a tally of names of Iroquois League chiefs, proportioned by number of representatives for each of the Five Nations, and suggested that the writer undertake its study.

Accordingly, the Cranbrook Institute of Science invited me to describe the specimen. Between wartime assignments, I took the opportunity afforded by the Cranbrook Institute to visit the Six Nations Reserve from September 15 to October 15, 1943, to make inquiries about the cane and to investigate its history and use in the Condolence Council. This search was coupled with the work of translating texts of the rituals that were collected by my predecessor, the late J. N. B. Hewitt, and by Alexander Goldenweiser for the National Museum of Canada. Both of these ethnologists had worked at the Six Nations Reserve with Chief John A. Gibson, father of my interpreter Simeon, and Hewitt had retained Joshua Buck and Chief Abram Charles. To advance the translation of these manuscripts relating to the Iroquois League, the American Council of Learned Societies in 1941 had awarded me a grant-in-aid of research. A renewal made in 1942 had not been used, but the Council made it available for this study in the fall of 1943. Study of the Condolence Council constituted the central problem of field work in the spring and fall of 1945, supported by the Viking Fund of New York City, and the present study is written with that background material in mind (Fenton, 1946; and 62d and 63d Annual Reports of the Bureau of American Ethnology).

OPINIONS OF RITUALISTS AT SIX NATIONS

While in the field and between trips during this study I could count on the interest of Chief Alex General of the Upper Cayuga band, present holder of the title *Deska'heh*. On seeing a drawing of the stick, Chief General confirmed the fact that the front is a tally of the 50 chiefs in the League. In this he received the support of Simeon Gibson in 1943 and the latter's brother Chief John Hardy Gibson who was installed in 1945; the Gibson brothers in 1939 and 1940 had mentioned the existence of such a cane. On the Three Brothers side, David Thomas sustained the identification, and although he is an Onondaga warrior, nevertheless he commands the respect of the chiefs in such matters and they rely on him to speak for them and to perform principal roles in the Condolence Council, including Eulogy Singer and Speaker of the Requickening Address (Hewitt (Fenton, ed.), 1944).

What we have designated the "back" of the stick, because it was least obvious in the field, presented more of a problem to informants. When Simeon Gibson looked at it, he was obviously puzzled as to its meaning, save the symbol of the "longhouse with two smokes" which is clear to any Iroquois. He remarked:

It is too bad that all the Cayuga chiefs are now dead, such as Robert Davey and Abram Charles, who were living at the time Andrew Spragg used the cane when singing on the road. It is hard to know [from the characters] just what he meant; he put down just his own idea.

At the time (1943) Simeon doubted that the present singer for the Cayugas, Charlie Van Every, ever saw the cane, but up until the present it has not been possible to question him.

To Chief General, however, it is clear that the back of the stick depicts the beginning of the *Hai Hai* or Eulogy chant, when the condoling chiefs of the Four Brothers side first assemble at Lower Cayuga Longhouse before starting out on the road to Onondaga. When first they gather at Lower Cayuga, the condoling chiefs appoint a man as leading singer to start the Eulogy. Pacing to and fro in the longhouse, the singer carries the Eulogy through its long introduction all the way to the end, as far as it is depicted on the back side of the Condolence cane, before turning the stick to call the name of the first Mohawk title at the moment that he steps out of the longhouse door to lead the procession over the road to Onondaga.

Recalling the forepart of the Eulogy chant, Chief General was able to adjust his version to the circular symbols or ciphers (O, and ooo), by equating each repetition of the recurrent phrase *Hai hai-ih* to a

circle. In other words, it would seem that the symbol O or ooo, the circles or ciphers, are as notes in a musical scale, indicating high, middle, and low tonal position to the singer. This theory did not work out entirely, however, particularly after reaching the two parallel sets of linked circles that slant from lower left to upper right (fig. 2, 2). Although the next several characters present enigmas, the characters depicting a prostrate man illustrate that part of the introduction to the Eulogy which sings of the founding chiefs lying in their graves on the laws that they legislated.

One further note on the question of missing pegs, noted in the description. John Smoke further told Howard Skye, who recognized the cane which he had seen as a child and heard about all his life.

One other thing. Whenever a chief dies a peg is pulled out. There is no peg there when a chief dies. The peg is put back in place whenever they install a new chief.

Howard Skye took me to meet old John Smoke in November of 1945. When we found him at home, the old Cayuga had contracted to help a white neighbor press hay. With this obligation in mind he would not discuss the Condolence cane, although he acknowledged that the blueprints I showed him were of the cane he had discussed with my younger interpreter. Copies have since been supplied to several of the chiefs at Six Nations. But to postpone this report until after another field trip does not seem warranted, although one can always get new information.

With these leads, we shall proceed presently to a specific analysis. But first let us take up related mnemonic devices and the use of canes in Iroquois ceremonialism before discussing the function and composition of this cane in particular.

CANES IN IROQUOIS CEREMONIALISM

Old men and supernaturals.—Among the Iroquois, old men and supernaturals carry canes or staffs. A stick is a mark of distinction that cannot be entirely credited to the Iroquois of Grand River living among carriers of British culture in Canada. Essentially the Iroquois are landmen, and they are continually traveling on the road. As youths and young men they maintain a tradition that Iroquois warriors are renowned runners; their fathers point to Tom Longboat, who they say in his youth trained by running around the concessions of Six Nations Reserve wearing rubber boots and later became Canada's greatest distance runner. Andrew Spragg belonged to this tradition. As middle age approaches men begin to feel knee injuries

that have been sustained during lacrosse matches in their twenties and thirties, and sooner or later they affect a staff when traveling the roads and woodland paths. Simeon Gibson in his fifties always carried a stick, one of several that he picked up from beside the gate, another that he left at the store where he traded, or that he cut along a fence row, or retrieved from the roadside where he had cast it for a passing ride. This is hardly an individual trait.

Rather the staff is deeply rooted in the Iroquois conception of the ideal older man. "Old man" has a connotation of affection and respect. Certain classes of supernaturals are called "Our grandfathers." This is how the people address, in prayers, both classes of maskers, the wooden faces whom the people impersonate by wearing masks of wood and the Husk-faces; both carry wooden staves. The masked members of the False-face Society and the Husk-faces command great respect. In praying to the tutelaries whom they represent, the priest says: "And now your cane receives tobacco, which is a great hickory with its limbs stripped off to the top."

All the actors in the ceremony carry peeled staves of hickory of about their own height. Likewise, the Husk-faces individually carry staffs or shorter canes which they dance around. It is presumed that such impersonations of the grandfathers, these masked shamans, project stereotypes of statuses and roles that obtained in former times.

The implement of a chief.—Likewise a cane is the implement of the chief. Chiefship is the highest status in Iroquois society. In becoming a federal chief, one who is destined to serve as an officer of the League, a man gives up the right to follow the war path and puts behind him the glory of individual achievement; henceforth his life is tied up with the affairs of the council and his business is peace. This honor seldom befalls a man before his middle years, when it is natural that he should lay aside the war club and take up a staff. The symbolism is fortified, moreover, by the fact that each federal chief has a subchief or deputy who acts as his messenger and sometimes his speaker, and this functionary is sometimes referred to as "The Cane" or "The Ear, who sits on the roots of the Tree," the chieftain whose subchief he is (Hewitt, 1920, p. 535). A cane figures as a status symbol of chiefship in that section of the Deganawi'dah legend that treats of condoling and installing federal chiefs in office. Therefore, the so-called Chief's canes that occur in ethnological collections from the Iroquois do not represent necessarily a recent development in woodcarving which followed new tools. The cane idea is old; the specimens are of the recent historic period.

Other Condolence canes.—The carved cane is a new idea which

came in with the jackknife. So John Echo, an Onondaga of Six Nations Reserve, told F. W. Waugh in 1912. Canes were formerly made of a wood called *dusishää'*; shafts were cut, dried a little, and bent. Bent-wood canes became a ready source of cash income in the decades preceding and following 1900. Waugh describes a form for bending round-handled canes which he saw at William Poudry's at Tonawanda Reservation, N. Y., during the same year. After the manner of logs for scraping and working skins, one end rested on the ground, the high end on two or three legs. The high end was flattened around a vertical cylinder which was mortised into the log, and a vertical pin placed next to it made a vise and shaping block for bending canes, lacrosse sticks, and snowshoe frames. The Iroquois bend hickory when it is green, and John Echo averred that steaming was not an old method of wood bending among the Iroquois. Sticks for snowshoes and so on were generally used round, after drying just a little, and then roasted or warmed up beside the fire, which was sufficient for bending (Waugh, 1912, Note Book B (Ms.), p. 27).

In the collections of the National Museum of Canada are four so-called Chief's canes, which Waugh collected at Six Nations Reserve in 1915. Waugh got two of these from Cayuga Chief David Jack, his principal informant on material culture; he purchased the third from George Davis (Onondaga), and the fourth came from his interpreter, John Jamieson, Jr. (Cayuga) who found it along the road. (Pl. 3, left to right.) The first is a plain, curved-headed cane of hickory which belonged to David Jack's grandmother's husband (Cat. No. III.I. 1035); modern canes of this type have the bark stripped from the wood. David Jack gave for cane: *dá'ditra'ä'na'* (Cayuga); *da'ditshä'* (Onondaga).

The second specimen has its handle carved to represent some waterfowl and the shaft is scored in intersecting lateral diamond grids; it belonged to David Jack's grandfather, who was also a chief, and it is said to have passed through the hands of four generations covering possibly a century, which is roughly the span that the Six Nations have occupied the Grand River. (Waugh, 1912, Notebook No. 4, front cover (Ms.), and Accession Records, National Museum of Canada, Cat. No. III.I. 1034.)

The third specimen is ascribed to the ceremony of installing new chiefs and therefore belongs to this discussion. It was a natural, unworked stick with a knot at the head which was carved readily into the effigy of a bear or wolf, and may have suggested its purpose to the maker, although Waugh (1915, Notebook No. 7, back cover (Ms.)) says that neither corresponds to George Davis' clan which

was deer. Attached to the cane is a single string of wampum: "The number of beads is said to have signified the number of chiefs, the white beads indicating the leading chiefs, the blue the Pine Tree chiefs. . . . The cane is said to have been used for many generations for the purpose described" (Collectors Notes, Accession Records, National Museum of Canada, Cat. No. III.I. 1068 a & b). This datum to the contrary, as we shall see, neither the number of beads nor the pattern of their arrangement agrees with the grouping of chiefs by tribes in the Iroquois Confederacy. There are 10 white beads, which is precisely the number of Cayuga federal chiefs, but we are unable to account by this reckoning for the rest (the number of blue beads) as Pine Tree chiefs. Assuming that the 10 white beads stand for leading chiefs of committees in the Council of the League we get nowhere because "Pine Tree" chiefs did not belong to the League Council.

As we read them, the total number of beads is 38: 10 white and 28 blue. Starting at the top of the loop and proceeding counter-clockwise, the arrangement is: 6b, 1w, 2b, 1w, 1b, 1w, 2b, 1w, 2b, 1w, 2b, 1w, 4b, 1w, 2b, 1w, 2b, 1w, 2b, 1w, 3b. Grouping these in pairs, the following rhythmic patterns emerge:

6-(1), 2-(1), 1-(1),
 2-(1), 2-(1), 2-(1),
 4-(1),
 2-(1), 2-(1), 2-(1),
 3-(0).

Whichever way it is read, a similar pattern comes out. But taking it as it stands above, the second and fourth lines of repeated units of 3 could refer to the three committees of each of the Mohawk and Oneida committees of chiefs in the Bear, Wolf, and Turtle clans, of which the bracketed figure, standing for the white bead, would be the leading chief. The rest of the combinations do not work out since the total number of beads does not correspond to the roster of federal chiefs, which is 49 or 50. If the string were intended to symbolize the federal chiefs in either tribal phratry, the number is wrong, since the chiefs of the Three Brothers side (Mohawk, Onondaga, Seneca) comprise 31 titles, arranged 3-3-3, 6-1-2-3-2, 2-2-2-2; and the chiefs of the Younger Nations or Four Brothers side (being only Oneida and Cayuga in Five Nations) are 19 titles, arranged 3-3-3, and 2-3-3-2.

The fourth cane (Cat. No. III.I. 1037) is one of those freaks of nature, a spiral produced by climbing bittersweet, that the Iroquois

love to get for a walking stick. Evidently its owner did not prize it highly, since he left it by the road.

Another carved Chief's cane was seen in the Royal Ontario Museum of Archaeology (Toronto), it being part of the Chiefswood collection of Miss Evelyn H. C. Johnson (Cat. No. HD 12622). It once belonged to Daniel Springer of Six Nations Reserve, Brantford. It is Janus-faced and measures 31.5 inches. (Pl. 4, *a* and *b*.)

There are two such canes from the Huron or Iroquois of eastern Canada in the ethnological collections of the Provincial Museum of Quebec. No information is available on their provenience, except that they belonged to the Government before the establishment of the Quebec Provincial Archives Office and were transferred to the Archives without accession records, if such existed. One bears the head of a dog or wolf, and the rope motif of the stick appears to represent grass snakes, according to Dr. Antoine Roy, Quebec Provincial Archivist, to whom I am indebted for the photograph and for an intensive search.¹⁷ (Pl. 4, *c* and *d*.)

Four fine examples of carved canes were collected in 1918 by S. A. Barrett in western New York and Ontario for the Milwaukee Public Museum. These specimens were seen and examined briefly during a visit to the museum August 27, 1947, thanks to the courtesy of the curator, Robert Ritzenthaler, and since then both he and Dr. W. C. McKern have supplied data from Barrett's field notes, which did not accompany the specimens or were not evident in the catalog. The two finest specimens of Chief's canes bear animal-effigy handles, bear and wolf. (Pl. 5, *a* and *b*, and pl. 6, fig. 1.) The bear-effigy cane (Cat. No. 54,962/16,425) was found in the Museum without data. The wolf-effigy (Cat. No. 24,598/6158) ingeniously swallows the shaft of the cane which measures 37.5 inches. (Pl. 6, fig. 1, *b*.) Collected in Ontario in 1918, it obviously comes from Six Nations Reserve. A third, obviously quite modern, is crudely done; it also has the wolf effigy; and on it is carved the title S'agogen'he' and the year 1918. (Pl. 5, *d*, and pl. 6, fig. 2, *b*.) The title is that of the twelfth chief on the Onondaga list in the League Council, and means "he saw them" or "he saw the people." The main interest that attaches to the specimen is the proof that individual chiefs had carved canes, and here is one bearing his title, a clan effigy, and the probable date of his installation. Unfortunately, the legend does not appear in the illustration, and the catalog number is not at hand.

Greater interest attaches to the fourth cane in another connection.

¹⁷ Roy, Antoine, personal communication, April 16, May 5, 1947.

While not a Chief's cane, it is in character. On the head of a vine-spiraled stick has been carved a miniature False-face. (Pl. 6, fig. 2, *a*.) The specimen (Cat. No. 24,103/6084) is recorded as collected among the Senecas of Cattaraugus Reservation in western New York by Barrett in 1918, but according to his field notes it was carried by the man who is annually elected to lead the march of the False-faces from one council house to the other at the Midwinter Festival. The latter notes about the cane are in a section marked Onondaga and may refer to the Six Nations Reserve.¹⁸

Parker collected and published (1916, p. 112) a record staff for the Condolence and Installation ceremony of a League chief; it is a round staff with one flattened surface on which are drawn pictographs (illustrated, p. 111), 18 in number, which refer to stations in the Requickening Address, but not to the roll call of chiefs. The specimen is in the New York State Museum (Cat. No. 36907). The pictographs, nevertheless, show affinity to the drawings on the cane of Andrew Spragg, which are in the same style.

In the winter of 1941 Chief Joe Williams of Seneca Longhouse at Six Nations on Grand River, showed me a Chief's cane of a type that resembles the stick of George Davis, already described, in the National Museum of Canada. None of the above specimens, however, is like the specimen under discussion.

The brothers Simeon and Hardy Gibson came the closest to describing a cane that they had seen in use among the Lower Cayuga and which had the precise arrangement of pegs for denominating the chiefs, although it was a simple mnemonic and lacked accompanying pictographs. In fact, Simeon volunteered to reproduce such a cane and he was more accurate in describing it than his brother. We made a drawing at the time of the interview but no such cane ever materialized (fig. 1, *b*). Starting at the top, which he gave a swordlike handle, Simeon said that it would have three groups of three pegs for the three committees of Mohawk chiefs, with the same repeated for the Oneida chiefs, followed by groups six, one, two, three, and two in a line for the Onondaga chiefs, an arrangement of two, three, three, and two for the Cayuga chiefs, and four groups of two for the Senecas. Except that they were spaced in groups or committees, the pegs extended in a continuous line from the top to the end of the roster, near the foot of the cane. Groups of chiefs were separated by a line, and two lines segregated tribal councils.

In another interview Hardy Gibson arranged the tribes in phratries

¹⁸ McKern, W. C., personal communication, October 2, 1947.

and grouped the chiefs in committees across the cane (fig. 1, c). His arrangement called for Mohawk at the top, Seneca and Onondaga near the center; then a double line to separate this moiety of tribes from the Cayuga and Oneida toward the foot. Such arrangement, of course, resembles the seating of the tribal councils at the Six Nations Court House in Ohsweken. (Hewitt, 1944, p. 85; Hewitt and Fenton, 1945, p. 306.) Hardy's arrangement of pegs on the cane entailed three horizontal rows of three dots for the Mohawk, two rows of three and a row of two, or three rows of two—Hardy was uncertain—for the Seneca; he was not sure of the Onondaga arrangement; but the Cayuga he knew was a row of two, two rows of three, and another row of two, and Oneida simply repeats Mohawk. Lacking the cane at rehearsals, they use white corn, Hardy recalled, so the arrangement of pegs on the stick is the pattern for laying down corn at rehearsals for the Condolence Council.

Cane for Moccasin game at chief's wake.—Collateral support for the roll-call stick comes from two other wooden records from the Iroquois of Six Nations Reserve. In June of 1916 J. N. B. Hewitt collected a rather nice example of a cane with a crook for use in the Moccasin game at a chief's wake (37th Ann. Rep. Bur. Amer. Ethnol., p. 14, 1923) (pl. 7 of this paper). This unusual specimen (U.S.N.M. No. 384288) had not been described at Mr. Hewitt's passing (1937), and his notes on it are scanty indeed, being limited to a single page (B.A.E. Ms. No. 3506). Thirty years is a long time for a people to do without a bit of ritual paraphernalia, so that small likelihood remains that diligent inquiry will discover how the cane functions in the Moccasin game or how its symbolism serves to prompt condolence speakers. Nevertheless, among specimens seen in the Royal Ontario Museum of Archaeology in November 1945, Howard Skye identified No. 19,836 as a bundle of stick counters used in the Moccasin game, of which 50 is the number used for a child, the full 100 being for an adult. The counters are of white pine, as is the drum beater which accompanies them. At the wake, clans divide into phratries and sit on opposite benches. Four moccasins are placed on the floor between them, the pile of counters at one side. The singers have the drum, and one of their number hides a bullet or stone in one of the moccasins before him; the seekers have the wooden pointer or cane. The man who has the cane picks one moccasin. If he finds the loaded one on the first try, that ends the singing; but if he fails, the pointer goes to the man next to him and the singers continue. At each miss the singers (hidiers) get one point. When the opposing side finds the object, they receive a

point (?) and the drum. At the last song, along about daybreak, the master of ceremony burns the counters one at a time—each counter represents a spirit, a ghost—and he also burns the drum stick, and he breaks and burns the pointer. He removes the head of the drum. How, then, these specimens survived for museum collections is remarkable.

Possibly the photographs of the stick published here to illustrate Mr. Hewitt's brief notes that follow will promote a favorable opportunity for someone to observe the Moccasin game at Grand River and augment our meager data on the relation of the symbols to the content of speeches.

Brantford, June 30, 1916.

Notes on cane with crook used in Moccasin game:

BACK OF CANE

		Pl. 7, fig. b
1st design	represents "evil, sickness, death"	1
2d design	" " "a man, or person"	2
3d design	" " "a wampum belt"	3
4th design (small saw teeth)	" " "black wampum"	4
5th design	" " "a lodge"	5
6th design (crossing paths)	" " "all are notified"	6
7th design (squares)	" " "hall of meeting"	7
8th design (semicircles)	" " "people"	8

[Cf. third unit on the back of the Spragg Condolence cane.]

RIGHT SIDE OF CANE

All [the cross-hatched and chevron designs are said to] represent wampum belts received by the allied tribes. Note end of design showing wampum belt ending (suggesting diamond designs in the great belts of the covenant in New York State Museum (Parker, 1916; Clarke, 1931, p. 99 and fig. 35)). (Pl. 7, fig. c.)

LEFT SIDE OF CANE

		Pl. 7, fig. d
1st design	represents "evil, death, etc."	1
	[Cf. 1 on back, right. Note symbols of two persons close by.]	
2d design	represents "sun lost (to view) because of death"	2

[Eighth burden of Requickening Address (Hewitt, 1944, p. 74; Hewitt and Fenton, 1945, p. 314). Loss of Sky, the seventh burden, and Loss of Sun, the eighth burden, apparently intersect in this design.]

3d design	represents "the face of the dead"	3
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		Pl. 7, fig. d
4th design	represents "his lodge" (a typical log cabin on Six Nations Reserve)	4
5th design	" " "the world" (paths)	5
	[Cf. 6 and 7 on back of cane, which this and the following reverse and combine.]	7
6th design	represents "winding path of the dead"	8

For some obscure reason Hewitt and his informant failed to enumerate and interpret two units, of which there are eight, on this side of the cane. Following the house (No. 4) are two square units, the first of which resembles No. 7 on the back, "hall of meeting," with addition of diagonal lines, indicating that death has altered this assembly in some way; and the next or sixth unit, which is quite similar to No. 6 on the back, "all are notified." Then would follow the winding paths of "the world," and the "winding path of the dead," with its dentate margins like the string of black wampum symbolized in the third unit on the back.

The cane measures 38 inches over-all (pl. 7, fig. a), including the crook which has the effigy of a bear, possibly the clan eponym of its maker, at its head. The material is of white hickory (*Carya glabra* (Mill.)).

Vision stick of Seneca prophet.—The second wooden record from the Six Nations Reserve pertains to the revelation of Handsome Lake, the Seneca prophet; it is a pine stave some $31\frac{3}{8}$ inches in length, a maximum width of $1\frac{1}{8}$ inches, and a maximum thickness of $9/16$ inch. It is soiled with long use, and broken with a longitudinal diagonal break that has been repaired; and it is fitted with an eye at the top of proper dimension to admit the speaker's index finger. Dr. S. A. Barrett collected the specimen in 1918 on the Grand River for the Milwaukee Public Museum (Cat. No. 24601/6158), but from whom we do not know, and efforts to reach Dr. Barrett by letter have failed to elicit further information. While no data accompany the specimen, the incised pictographs are so clear that one may compare the legend with Parker's "Code of Handsome Lake" (1913) and recognize the beginning at *Dyononhsadegen*, "Burnt-house" (Cornplanter Reservation), when the Four Messengers appeared to the prophet in the month of May, 1799. (Pl. 8.) Rather than attempt a description of this specimen now and an analysis of its pictographs, suffice it to say that the drawings of houses, plants, and the human figures are in the same style as the figures on the roll-call stick of A. Spragg. The Handsome Lake stick, which is in character with the message and prayer sticks of the Shawnee and Kickapoo prophets, deserves a separate paper.

It is now established how the cane features in Iroquois ceremonialism and social life. Sometimes the cane is combined with the mnemonic record stick, but the latter has a separate form more nearly resembling the prayer and record sticks of Central Algonquian prophets and may refer to the same time level. Iroquois pictographs have a consistent style, the figures of humans maintaining a broad-shouldered narrow-hipped consistency found in war memorials of the eighteenth century.

ROLL CALLS OF OTHER FORMS

Roll-call wampum.—One of the most interesting records that has been ascribed to the period of the founding of the League is a roll-call wampum from the Mohawk of Six Nations Reserve that is now in the safekeeping of the National Museum of Canada. In describing the specimen, Diamond Jenness (1933, pp. 25-26) calls it the “. . . covenant or Magna Charta of the League . . ., the record of its foundation and organization, made by the Iroquois women at the command of *Dekanawida* and his associates. . . .” The late Mohawk Chief William Loft related the tradition that

. . . *Dekanawida* appointed fifty sachems from the five nations, . . ., made them join hands in a circle, and ordained that they should be of equal rank and bear individual titles. That they might remember their titles and position in the council house, he then devised this wampum record, which he entrusted to the keeping of an outstanding warrior, . . . who bore the title *Sharenhkhonwaneh*, “Majestic Tree,” . . . first sachem of the wolf clan in the Mohawk nation. The successors to this title . . . remained the official keepers of the record down to . . . Chief Loft himself . . .

Loft told how during the Revolutionary War it was buried by its keeper inside a brass kettle where it remained 8 years, to be dug up at the instance of Joseph Brant who obtained it for the ceremony of rekindling the council fire of the Five Nations on the banks of the Grand River in Canada.

The record contains upward of 1,800 white wampum beads to which Jenness attributes considerable antiquity, since X-rays show that they are drilled from both ends. The record is formed into a large circle by two entwined strings which symbolize “respectively the Great Peace and the Great Law” that were established with the beginnings of the League; and from the entwined circle depend 50 pendant strings to represent the 50 chiefs of the confederacy. “That representing the seventh Onondaga sachem, *Hononwiyendeh*, . . . keeper of all the records of the League, is slightly longer . . .”, serving as a guide in reading the record and in laying it out. Jenness says (p. 26) that the circle was laid down with all the pendants turned in

toward the center and with the long pendant representing the Onondaga wampum keeper to the left of the join in the circle. (The museum photographer in laying out the specimen inadvertently reversed it, or the negative was printed in reverse, to contradict the description in the text, because in the plate (p. 29) the long string appears at the right. The wampum circle is also illustrated in Jenness, "Indians of Canada" (p. 136, 1932), in a different orientation with the long string at the upper left, as his text states.) Beginning at the join and reading counterclockwise (clockwise in the published plate), there are 14 strings for the Onondaga federal chiefs, of which the long string is number 7 reading counterclockwise in the Onondaga group, then returning to the join and reading clockwise, 8 for the Seneca, 9 for the Mohawk, 9 for the Oneida, and finally 10 for the Cayuga. This left the Cayuga at the right of the Onondaga. Jenness' information goes on to state that it was in this order that the council sat.

There the Mohawk, if they were introducing a question, referred it first to the sachems of the Seneca nation, who sat on their right. When the Seneca gave their judgment the Mohawk referred it to the sachems of the Oneida and Cayuga. Lastly, the Mohawk laid it before the sachems of the Onondaga, who could express an independent opinion only if the other nations had disagreed. . . . if the nations failed to reach a unanimous agreement the matter was to be referred to the council of matrons for decision. [P. 26.]

The wampum circle groups the Onondaga chiefs at the right, the Senecas and Mohawks on their left, and the Cayugas and Oneidas on their right; we note first that the chiefs are grouped into two great moieties of 31 and 19 chiefs respectively, the first comprising the Mohawk, Seneca, and Onondaga, the other the Cayuga and Oneida. Second, the arrangement of tribal councils and sequence around the circle, or fire, is not the order of the roll call in the Condolence Council ritual which proceeds the length of the Longhouse of the League, from its east door, the Mohawk, to the western door of the Seneca. Third, if the Onondaga were seated north of the fire as they sat at Ohsweken on Grand River, the wampum circle would place the Seneca and Mohawk on their left, and the Cayuga and Oneida on the right; which was their relative orientation, but it is my impression that in the Ohsweken council house the Mohawk chiefs sat immediately next to the Onondaga with Seneca chiefs at one remove, and likewise the Oneida on the right (west) and Cayuga and chiefs of other nations near the door. Finally, the ring of chiefs around the council fire more nearly symbolizes the order of business around the council fire of the League than it does the seating of chiefs (unless this changed in

later times) or the roll call of the League. This argument, nonetheless, does not deny that one who understood it could employ the mnemonic circle of wampum for enumerating the chiefs of the confederacy.

List of chiefs by Seth Newhouse.—Toward the end of the nineteenth century the Iroquois record keepers had ceased to rely entirely upon wampum strings and other devices for remembering the roll call of chiefs. From a list of chiefs in the missionary orthography that was instituted by the Anglicans and the S. P. C. G. (Society for the Propagation of the Christian Gospel) for writing Mohawk and printing hymnals and prayer books it is clear how the ancient mnemonics were combined and labeled with the new writing. The manuscript, which was among Mr. Hewitt's papers in the Bureau of American Ethnology, was evidently written by some Iroquois scribe, who was familiar with both systems, on a piece of folded letter stationery bearing in the upper left corner of page 1 the circular seal of what appears to be "C. R. Chisholm & Co." around a wood-burning locomotive. Informants on the Six Nations Reserve recognized the name, which is hardly legible, as Chisholm, a firm of Toronto lawyers who had been retained by the Six Nations chiefs; and Hilton M. Hill knew an A. G. Chisholm, barrister, who was solicitor for the Six Nations in the Grand River Navigation Claim and who had died about 1942. A. G. Chisholm, barrister, had offices in London, Ontario, according to Charles Cooke, retired member of the Indian Department, Ottawa. Mr. Hill declared that the document is not in the hand of Josiah Hill, for many years secretary of the Six Nations council, but suggested two other possibilities. Chief William Loft spoke Mohawk, and he was a great penman and natural artist, as witness the memorial in burnt leather which hangs in the council house at Ohsweken; he was the only man who could speak the Mohawk of the League ritual and who could write well, and he died about 1939 or 1940. But it is more than likely that Seth Newhouse was the scribe. Newhouse manuscripts in the archive of the Bureau of American Ethnology are in the same hand, which suggests that this Mohawk chronicler and codifier of custom law printed the list on a borrowed sheet of lawyers' stationery. The identification both supports and is confirmed by the analysis of a recently discovered Iroquois Constitution which is the work of Newhouse (Fenton, 1949, p. 144).

Apart from the list of chiefs, on the margin of the first page appears the mnemonic system for remembering how many titles belong to the five tribes, how the tribal councils are spaced to signify intertribal relations, and what are the classes of chiefs in each tribal council—all nicely labeled by tribe, and enumerated into 16 classes (pl. 9, and

fig. 1, *d*). Why Newhouse stopped at 16, the first Seneca class, remains a mystery, for 19 classes or committees may be distinguished (fig. 1, *a*). The mnemonic is almost the same as the one on the cane, and it is identical to the pattern for laying out kernels of corn at rehearsals. It would seem that Newhouse had started with an old system and then proceeded to his list. The same names appear as headings for the tribal rosters, and the numbered classes of chiefs are transferred from the mnemonic to the list itself where the titles are carefully spelled out (pls. 9 and 10). Newhouse recorded the same mnemonic as well as the titles, also in his great work on the Constitution (Fenton, 1949).

Numbers in parentheses are written in bold ink. They are followed by penciled capitals, U.M. and L.M., in some cases, denoting Upper Mohawk band and Lower Mohawk band, respectively.

In the same hand at the very top of the sheet is written "(U.M. are cousins)"; beneath the first tribal name in parentheses appears: "One totem of another family of the same totem are brothers." (Pl. 9.)

The second page has been altered less than the first. Penciled addition upper right. The notes on the Ball and Eel clans at 23 and 29 are in longhand purple ink. A suffix has been added in pencil to 25, making the name correspond to modern usage; the enumerator who added numbers changed the prefix on 29. (Pl. 10.)

Penciled notes link the 8 Seneca chiefs together in pairs: "1 and 2 are cousins"; 45 and 46 are cousins; 47 and 48; 49 and 50. (Pls. 11 and 12.)

Mnemonic pictographs of Chief Abram Charles.—Based on the same mnemonic but of a different character from the list just described are the mnemonic pictographs of Cayuga chief Abram Charles which Hewitt collected and partly described and which the writer brought out as a footnote to the present study (Hewitt and Fenton, 1945). Chief Charles could not write or read such a list as his contemporary prepared, so he reverted to an older method for illustrating the spatial arrangement of tribes and tribal rosters. He recorded a series of grouped dots in the arrangement that he followed in laying down kernels of corn when instructing Eulogy singers in the roll call of chiefs, and the identical pattern is found in the arrangement of pegs on the Cayuga Condolence cane (fig. 1, *a* and *b*). Moreover, he composed pictographic representations of the titles, which again have a general resemblance to the pictographs on the cane.

Pattern for laying down corn at rehearsals.—There seem to be two

slightly different arrangements for putting down kernels of corn at rehearsals. The first arrangement is a straight-line sequence, staggering the tribal rosters and grouping chiefs of a class closely together. It appears in Charles' notebook (Hewitt and Fenton, 1945, pp. 304-305), in the cane diagram by S. Gibson, and on the Cranbrook cane (fig. 1, *a* and *b*). Possibly this is the method of the Cayugas. The second arrangement retains the straight-line sequence for groups of chiefs that are related as brothers to express phratrie alignment, but differs from the first in putting down pairs of kernels laterally to symbolize a cousin or intermoiety relationship that obtains between leading chiefs who share the roles of firekeepers, doorkeepers, and may be noted in the arrangements of the Onondaga, Cayuga, and particularly the Seneca tribal rosters (fig. 1, *c*, *d*, *e*). The second is an Onondaga pattern; it is employed in the manuscript lists of Seth Newhouse; and I observed the mnemonic in operation among the Onondaga at a rehearsal which I attended on the Six Nations Reserve, Canada, on November 18, 1945. The several mnemonics are contrasted in the accompanying illustration (fig. 1). A possible third entirely lateral arrangement was recalled by Chief John Hardy Gibson (Cayuga) in 1940 which has already been described (p. 34); since he had participated with his Seneca father on the Three Brothers side of Condolence Councils, his is probably not a Cayuga arrangement (fig. 1, *c*).

FUNCTION: A REMINDER TO THE EULOGY SINGER

REHEARSALS

The cane served to remind the Eulogy singer during rehearsals and in the actual ceremony of the Condolence Council. When, for example, the Three Brothers (Mohawk-Onondaga-Seneca) receive the short white string of wampum notifying them that one matron of the Four Brothers (Oneida, Cayuga, etc.), whom the Cayuga speaker represents, is ready to install a chief, they confer to set a date for the installation which usually is held 30 days afterward. The date of the Condolence Council may not be set for summer, but it must be held in the fall after the crops are in and the plants are frosted, or it may be held in early spring before the buds are on, but late enough so that the paths are not muddy, for which reason the autumn is far preferable.¹⁹ The chiefs on both sides meet nearly every

¹⁹ The tabu on singing the Condolence ritual rests harder on modern ritualists than it did on their grandfathers. At present the chiefs will not consider the question of a Condolence between spring and fall. It is considered too sacred

other night to rehearse the songs during the weeks preceding the installation.

At rehearsals of the Four Brothers (Oneida, Cayuga, and dependent tribes) the cane was present, but when it was not they used white corn, setting out a kernel for each of the Six Songs and for each of the 50 chiefs denominated in the roll call. The Three Brothers, lacking the cane, merely use corn.

Only the Cayugas had a cane. Spragg was its keeper, and Chief Alex General remembers that the usual way at rehearsals in the lifetime of Chief Abram Charles (mother's brother of my informant Chief John Hardy Gibson who was installed as his successor in 1945) was that they made a kettle of corn soup for a midnight feast. Kernels of corn were employed for teaching neophytes the order of the roll call. Chief Charles used to lay down a kernel of corn for each man (chiefship title), telling the relationship of that status to other chiefs in the same group, the groupings in the tribal council, and the relationships between the tribes of the League. Chief Charles called the name for each kernel of corn as he put it down. All watched. When he got through he would say, "Now, who is going to try it?" Some individual would volunteer and take the cane to aid his memory.

The learning process extended to other members of the household, including daughters. A daughter of Chief Charles, the late Mrs. George Buck, recalled how her sister, then a little girl, could go through the whole Condolence ritual, and that after a rehearsal she would take a cane and pace back and forth inside the house chanting the Eulogy and calling the names of the founders, which she had learned by hearing her father instruct the men. No woman, however, to our knowledge undertook this role at a public ceremony. Nevertheless, we can understand how matrons carry the ceremonial culture and critically audit the ceremonies of the chiefs whom they install.

The Three Brothers side who do not have the cane use the corn. They used to rehearse at the home of my interpreter, Howard Skye, himself a Cayuga as were both his parents, because it was central to the Onondaga neighborhood. Skye is treasurer of the Onondaga Longhouse; his father was deputy chief to Abram Charles. In rehearsing, the Onondaga chiefs and their colleagues used six kernels

to sing or discuss between condolences—"too sacred to play with." In 1883 a Condolence was held at Onondaga Longhouse on Grand River in July, after many postponements (Hale, 1895, p. 48), which is much later in the season than accepted native theory will allow or the present chiefs will admit. And David Boyle attended one in early May of 1905 at the same place (Boyle, 1906, p. 56).

of corn for the Six Songs, and one for each of the 50 chiefs. Of his early education in the ceremony, Howard said:

It is a strange thing, but when I was a small boy, I could name all of the 50 chiefs in the League. An old man came and stayed at our house one winter. He drew a set of pictures like those of Abram Charles [Hewitt and Fenton, 1945] and taught me from them. I learned all of the roll call. When I was about 12, I left the Reserve, my father having died, and I went out among the whites to work, staying until about 1930, when I came home some 15 years ago.

How the Iroquois learn a ceremony was brought home to me when I attended a rehearsal at the Onondaga Longhouse with Howard Skye on the afternoon of November 18, 1945. It was strictly a men's affair, only chiefs and warriors being present, and the atmosphere was informal but restrained. Opposite the single door, two parallel benches had been placed where the chiefs hold council at the men's fire. Onondaga Chief Joseph Logan (Dehadoda'·ho') was in charge. He opened the meeting with the regular prayer of thanksgiving, and announced why they were met. At the far end of the bench nearest him he laid out the 15 strings of Requickenning wampums, from left to right, starting with the first three, then a space and the rest, in order toward the women's fire, so that the fifteenth string lay across the end of the bench and the first about 18 inches away. He merely named the strings as he put them down, and discussed them with his colleague David Thomas who later made the Requickenning Address in the ceremony. During most of the rehearsal "Dawit" concentrated on the strings, apparently going over the "words" in his mind.

The order of ceremony is always reversed in rehearsal, according to Howard Skye, which bothered me as I had thought that Requickenning came last. Secondly, they alternate singers by condolences; David Thomas having sung the previous fall, the role this time fell to Roy Buck, a relatively young man in his thirties. In this way the roles are shifted among individuals and a knowledge of the ceremony is shared and preserved.

Chief Logan having laid out the wampum strings, Roy Buck put down the corn. Starting near the end of the bench by the first wampum string and proceeding in the opposite direction, right to left, he first laid out 6 kernels for the Six Songs. Then toward the midline of the bench, 8 kernels in 4 lateral pairs for the Seneca chiefs; then over the midline and to the left, 10 kernels for the Cayugas, a lateral pair of doorkeepers, a line of 2 groups of 3, and another lateral pair for the firekeepers. One of the latter kernels, I was told, which represented the vacancy to be filled at the installation, should have been placed to one side, but Roy Buck as a learner neglected this

bit of ritual, and Chief Logan who ordinarily lays out the corn at rehearsals overlooked the omission. The other chiefs present, if any one of them noticed the lapse, failed to mention it. The purpose is obviously to remind the Eulogy singer when he reaches the vacant title to insert appropriate phrases of tribute (Fenton, 1946, p. 116). Going back over the midline to the side of the Seneca, kernels were put down for the 14 Onondaga lords, as illustrated (fig. 1, *e*); next came the 9 Oneidas in a line of 3 three's; and likewise the Mohawks, but over the line on the side of the Three Brothers. When he had finished the League was laid out in moieties.²⁰

The ritual of the Six Songs was led by Roy Buck, the last song being reserved to sing after the first part of the following chant, just as in the ceremony. Over the Forest was entrusted to Peter John, a Mohawk of about 60, who had the words written out in a notebook into which I suspect he had copied them from Hale. He stood up, adjusted his spectacles, and paced to and fro with a cane, holding the notebook in one hand. Over the Forest (first part) was followed by the sixth song.

As in the ceremony, each song of the six is raised by a leader who traverses the whole length of the song before it is picked up by the choir of chiefs and repeated. All who desire to learn sit in with the chiefs or behind them. Among them I noted William (Billy) Buck, the accomplished Seneca singer, who had recorded for me in 1941. He was mastering these six songs to add to his already considerable repertoire.

Over the Forest (part 2) followed, and here Peter John made frequent reference to his notes. No one else seems to know this chant. Since he later performed this role in the ceremony, it appears that no one else is learning it.

Not so with the roll call or Eulogy, which also devolved on Roy Buck. From his place near the bench where the corn lay, young Buck stood with a cane and paced the length of the house to the far wall, where he turned abruptly each time and came back slowly chanting. I mention this cane because the Onondagas do not have a special Condolence cane, but nevertheless a stout, bent-wood cane is used. Each time a title is sung out in the roll call, the chiefs of that nation

²⁰ Since I was unable to make notes at the time, no objection was taken to my reproducing the diagram on the flat sides of one lead pencil with the point of another. The chiefs present, if they noticed my industry, seemed to think it quite appropriate for me to reproduce the mnemonic. Notes were written afterward.

cry: *Yo hε*..... ; *hi*..... and the others answer: *yε!*
(The first is high, the second low, rising, and the last abrupt.)

While this was going on, Chief Logan and David Thomas, the principal professors of the rites, sat back and let the younger man perform. Chief Peter Buck, father of the tyro, sat by as his son rehearsed. Chief Buck himself later performed this role inside the longhouse, after his son had carried the Eulogy over the road, on the day of the installation. Chief William Sandy and others of the elder chiefs studiously watched the corn on the singers bench as the young man went through the roll call. As the singer completed the roster of each nation, the chiefs present raised the *yo*.....*hε*..... for each group denominated. The rehearsal thus is a session of education in ritual.

USE CONFINED TO THE LOWER CAYUGA BAND

That a cane was an indispensable symbol of officialdom on both sides of the League should be evident from the way singers of the Condolence rites were trained at Six Nations to pace the length of the house, cane in hand. Hale (1895, pp. 53-54) noted this, while Boyle (1906) failed to mention it; and Boyle is especially disappointing since he accompanied the party of the clear-minded from Lower Cayuga Longhouse to Onondaga Longhouse on an occasion when A. Spragg should have been at his prime. Neither the man nor his cane receive notice.

Although both sides used canes, the specimen in question was confined to the Cayugas. All informants agree. Simeon Gibson asserted that while the Onondagas (Three Brothers) did not use the cane, he supposed that conceivably they could use it because it had the names of the chiefs on it in pictures. David Thomas agreed with my observations that the Onondagas manage to get through the ceremony without such a cane. During the many occasions when Simeon Gibson accompanied his blind father, Chief John Arthur Gibson, and his father's brother, Chief George Gibson (Senecas), to condolence and installation ceremonies, the latter always sang on the road for the Three Brothers, and he never used the cane with pegs and pictographs. "He carried an ordinary bent-wood cane, for *the singer on the road always carries a cane.*"

If a singer on the road always had a cane, and if the specimen in question is the cane which Andrew Spragg carried when singing for the Four Brothers side, we can understand how that particular one came to be associated with the Lower Cayuga band and that phratry

of the League called the Four Brothers side of which the Cayugas take the leading roles among the Six Nations of Grand River. And until recently reproduced from drawings supplied by Cranbrook Institute, no other such decorated specimen was known to informants.

USE IN THE CONDOLENCE COUNCIL

Journeying on the road to the woods' edge.—On the day of the Condolence Council, when the Four Brothers install a new chief on the Three Brothers side, chiefs and warriors of the Four Brothers meet at Lower Cayuga Longhouse at about 11 o'clock and rehearse. The one who was appointed to sing on the road formerly carried the cane while chanting the Eulogy or roll call. Meanwhile, the Three Brothers are cooking at Onondaga and they send down their warriors with a portion of food for the rehearsing chiefs at Lower Cayuga. When ready to set out on the road for Onondaga, the Four Brothers dispatch a messenger, a warrior who is supposed to run the distance. As the runner enters Onondaga Longhouse to deliver the message, the mourning chiefs present stand and listen.

The Eulogy to the Founders of the League, or the roll call, commences at the fire of the clear-minded. This chant has four names: (1) it is called simply *Hai Hai*, a general name for the entire Condolence Council; (2) *Hai Hai* at'ahinǫ'ge, "the chant for going on the road"; (3) *hodihiwisa'ǫ hodihihsyoni·di*, "they founded the League of the Longhouse"; and (4) *uǫdathhnǫhsǫ'dedákhkwa'*, "calling at another house," or "what a nation uses for calling at another nation's house." And the singer of this chant carries the cane, mentioning all the chiefs by name who were founders, by classes and nations to which they yet belong. This was the role at which Andrew Spragg distinguished himself.

The introductory part of the Eulogy, of 18 phrases covered by symbols on the back of the cane, is chanted inside the longhouse of the clear-minded, and when the singer reaches the first title of the roll call, he goes out the door to take up the path to the fire of the mourners. On the road the condoling chiefs march to the place of installation in twos, forming a procession behind the singer with the cane. The *Hai Hai* has ancient cultural roots; it is mentioned in the literature on the Huron Feast of the Dead as the cry of the souls marching from the burial platforms to an ossuary in another village; Bruyas (1862, p. 23) noted the root "to take up the path"; its opening stanzas refer to the long-dead founders lying in their graves now overgrown with grass and brush having put the League as a pillow

to their heads; and the procession of condoling chiefs symbolically carries the bones of the dead chief whose place they are about to fill by raising up another. *Hai Hai* was a peace chant too. It is said that in the year 1661 "Atreouati . . . entered Montreal, crying 'Hay Hay,' which is a sign of peace. He was immediately received. They made him presents and good cheer, but as he went out he killed two men who were roofing a house" (Shea, 1880, p. 310). The French knew full well that the Iroquois were not above treachery on occasion.

None of my informants claims to have followed Spragg on the road, so I have no first-hand account of his behavior in this role. Simeon Gibson, who was always on the Three Brothers side with his father, remembered meeting the column of Cayuga condolers at the small fire beside the woods, or Onondaga common, where they greet one another with a speech of welcome, called At the Woodside, or at the edge of the brush. This is the place where the mourners shall take the condolers by the arm and lead them to the longhouse where the main part of the ceremony is completed. Simeon remembered that Andrew Spragg was always carrying the cane as leading singer coming over the road. The singer calls out the names of the chiefs on the road, and if he comes to the end of the roll call before arriving at the fire, which is always kindled within sight of the longhouse, he must repeat from the beginning until he gets there. He stops singing at once on arriving at the fire, and the procession following him draws near to the fire and forms a line, opposite the Three Brothers across the fire.

During the ceremonies which ensue at the woods' edge, the leader on the road stands by, others making the speeches, until the march is resumed to the council house (cf. Fenton, 1946, p. 112). In the protocol that is observed beside the little fire, which is kindled at the side of the road at the border between the village common and the line of thorny brush which once marked the wilderness, we have a vestige of an ancient custom that was invariably observed by friend or foe in approaching another town. The messenger going ahead of the party, the cries that were shouted over the forest, and message sticks all notified the receiving chiefs that the visitors would put down their packs at the edge of the clearing and wait until they were received.

After the reception, the condoling singer resumes his song, following two warriors who have been appointed to take the leaders by the arm and lead the party to the principal bench inside the longhouse. On reaching the longhouse he stops singing at the door and goes back to

the beginning of the chant. At this point usually his place is taken by another who has been appointed to sing inside the house.

Inside the longhouse.—"The singer picks up the cane used on the road" to repeat the Eulogy to the Founders from its very beginning to its end, walking up and down inside the longhouse. When he completes the roster, the singer who has carried the ceremony to the other nation's house picks up his cane, which ends his role and the use of the cane in the ceremony. It was the latter use of the cane (already noted, p. 22) in the ceremony of July 17, 1883, at Onondaga Longhouse which Hale (1895, pp. 53-54) observed. Since Hale does not mention that the staff carried was enhanced with pegs and pictographs we shall never know whether it was the present specimen.

SPECIFIC INTERPRETATION

The Eulogy to the Founders of the League, which is the processional hymn of the Condolence Council, holds the key to interpreting the symbols on the cane. Like the two sides of the cane, it is divided into an introductory Eulogy to the dead founders and a long roll call. Having now described and identified the stick, and showed the functional relationship of the pictographs and the mnemonic comprised of pegs to the performance of the Eulogy chant, it remains to analyze the text of the chant itself in order that we may interpret the specific symbolism involved. Although Hewitt had abundant evidence for making such an identification, it was not until I had discussed the specimen at great length with Cayuga Chief Alex General that I was able to make headway with the problem and utilize Hewitt's materials and the manuscripts of Seth Newhouse. Likewise the program of the ritual of which the Eulogy is a part became clear only on observing a Condolence Council in 1945.

BACK: INTRODUCTION TO THE EULOGY

Notes for the Introduction to the Eulogy follow the name A. SPRAG on the back of the stick. By holding a blueprint of the stick before him as he chanted the Eulogy, Deskaheh (Chief General) was able to adjust his Mohawk version to the drawings. Mohawk is the original language of the chant; Onondaga, which is now much used and was frequently dictated by Hewitt's informants, sounds different. We have checked Chief General's version against texts of the late Cayuga Chief Abram Charles (B.A.E. Ms. No. 1281-a) and Hale (1883) and find that, although he may not be letter perfect, his version is in character and fits. Other manuscripts of the version in

use by the Three Brothers side from Seneca Chief John A. Gibson (B.A.E. Ms. No. 890, 1907) (and Gibson to Goldenweiser, 1916—Ms. in my possession) and Onondaga Chief Joshua Buck (B.A.E. Ms. No. 1281-b, 1917 and 1920) were dictated in Onondaga primarily and do not fit the cane as nicely. Similar recordings were made for me by David Thomas in 1945. The order of the introduction in no two of these versions is precisely the same, for the "words" come in different order, tenses vary, and some variation appears in versions given Hewitt by the same informant at later sittings. My suspicion is that no two performers are ever precisely alike. Rather than reproduce here any one of the texts completely, it is the sequence of the pictographs and their possible meaning which concerns us.

Eighteen words or phrases are supposed to preface the roll call. It comes out to about 18 sentences or lines of poetry in the chant before the singer turns over the stick to commence the roll call, stepping out of the door to take up the path when he announces the first founder. Accordingly, having written the translation of several versions on separate sheets and compared them, it became possible to divide the recurrent phrases or elements and assign them to appropriate symbols. More than this, the exercise enabled me to run a blueprint of the back of the cane through the typewriter and write in the margins the appropriate lines beside the pictographs (fig. 2). Some idea of the poetry is found in the version of Chief General (1943).

Hai Hai (repeat four times; eight in all; and after each line below):

1

Now to commence at the beginning,
 Your grandchildren right
 Now take up the path;
 May you excuse them
 If here and there in the ritual
 They shall not perform it in order
 The way that you used to do it
 When all the words were together
 As you established it.

2

Now only abandoned fields overlie
 The places where your bones rest,
 Where buried beneath your heads,
 Where you lie on it as a mat,
 Where you rest on it as a pillow,
 Where you have taken it (into your graves),
 What you established (the League).

3

Scattered places overgrown with brush
 Where your heads rest in your graves,
 Where you have it under your heads,
 What indeed you established (the League).

4

Patches of soft lawn cover the places
 Where you met to legislate,
 When still you employed all the words,
 Ye founders of the Great Peace.

5

You did erect a great tree (elevate a chief),
 You have reinforced the house (the League).

Here the singer turns over the cane, calls upon the founders to listen, and steps out of the longhouse and sets out on the road as he calls the first title *Tekariho'kenh*.

The version of Cayuga Chief Charles, although in Onondaga, corresponds closely. Recall that he and Spragg were neighbors and that Charles also had made a set of mnemonic pictographs. His opening verse is longer, and the second begs the pardon of the founders for errors of sequence. The third adds a metaphor, "There the overspreading trees; all is covered with forest" to preface "abandoned fields . . . overgrown with brush."

The Gibson version, though shorter, opens differently.

1

Hear us then ye proprietors,
 You did complete it,
 The Great Peace,
 Hail Grandsires.

2

Now it has grown old,
 There indeed it is overgrown with brush,
 Where your bones lie buried,
 Are also the words (laws) as laid down, (etc.) . . .

Seth Newhouse in his manuscript of 1885 speaks of the Eulogy as "Pacification" or the Confederating Hymn (Ron-wa-di-nonh-senh-deh-thah), attributing it to Dekanawidah, author of the League (Fenton, 1949, p. 145). He succeeded in dividing it into 30 verses

and inserted the roster of founders obtained from Hale's informant, Old Smoke Johnson (1793?-1887), who used the orthography which Anglican missionaries had devised for Mohawk. Let us see how Newhouse, who wrote in both Indian English and in his native Mohawk, framed his lines.

1

I am glad, I am glad, Now hear ye. I am glad,
I am glad, The Rules of the Great Peace. I am glad,
I am glad, Which have been established by you. I am glad,
I am glad, Now it has become an ancient rule. I am glad.

2

I am glad, Nothing now remains. I am glad,
I am glad, But bushes here and there. I am glad,
I am glad, Your bones are now in the graves. I am glad,
I am glad, Ye who have made the Rules.—I am glad.

3

I am glad, Ye have taken there with you. I am glad,
I am glad, There you have them under you. I am glad,
I am glad, Really there are only deserted fields. I am glad,
I am glad, There your brains are buried. I am glad.

4

I am glad, There ye have them under your heads. I am glad,
I am glad, Ye who have made the Rules. I am glad,
I am glad, You have taken them with you. I am glad,
I am glad, Ye have the rules under you as a mat. I am glad.

5

I am glad, You did establish the rules. I am glad,
I am glad, Of the Great Peace. I am glad,
I am glad, Now indeed, I am glad, Hear ye, I am glad.
I am glad, Ye who were rulers (founders). I am glad,
I am glad, *Teh-ka-rih-ho-ken!* I am glad (etc.).

Now as to the cane (fig. 2). Beneath the name A SPRAG come approximately eight circles, which, I judge, may stand for the repetition of *Hai Hai*, that many times (1, a). I am at a loss to interpret the five tracks beside the circles (1, b), unless, possibly, they stand for the Five Nations which are denominated by the titles of their five leading chiefs—*Tekarihoken*, *Odatchehdeh*, *Adodarhohh*, *Deka'en-yonh*, and *Skanyadariyoh*—in the preface to the version of Joshua Buck. (Cf. pl. 7, b.)

Accepting as a second design unit circles connected by lines and a dot within a circle, Chief General thought that the dot and circle meant the "completed League" as originally established (2, *a*); the path through the villages of the Five Nations, which the condolers follow, is represented by a line from a circle through four dots (2, *b*); and the next figure, a line connecting two circles, but passing between five dots (2, *c*), I have assigned to the phrases which beg the founders to excuse errors of sequence and omission in the ceremony as they anciently performed it when all the words were together.

The next figure obviously refers to heads in graves, where the founders have taken with them what they decreed (3). Certain items appear beneath the surface, and the broken lines toward the sod in the next figure express movement.

The sod line (4, *a*) represents: "Now only abandoned fields overlie the places where your bones rest upon the things which you established" (4, *b*).

So with the next unit: ". . . overgrown with brush (overspreading trees, forests) (5, *a*), where you are lying on the mat of the law (5, *b*), where you have put it under your head as a pillow . . . (5, *c*), what indeed you established (the League)" (6, *a*). On the contrary, Chief General thought this figure (dot and circle) refers to grassy plots where they anciently met to legislate.

Next come a procession of leading chiefs of the Five Nations wearing horns of office going on the path (6, *b*) toward the longhouse with two smokes (7), which goes with the line: "You have reinforced (strengthened) the house (the League)" (via the Condolence Council). It also stands for their destination where the main part of the ceremony is performed, and, finally, where the new chief is to be raised (8). The last figure of the man is also a reminder to insert special praise to the Dead Chief when the singer reaches the vacant title (on the obverse side of the cane). "You did erect a great tree" is the line that applies here, since the chief is likened to a pine tree beneath which the people sit.

FRONT: THE ROLL CALL OF THE FOUNDERS

The Roll Call of the Founders of the League occupies the front of the stick (fig. 3). Here laid out, after the manner of kernels at rehearsal, may be seen at a glance the space relationship of the five tribes, how they are grouped in phratries and divided into moieties. Closer examination reveals the number of chiefs in each tribe, the

composition of committees or classes, and for each peg the title is suggested by a mnemonic pictograph. Clearly the space mnemonic by which the pegs are arranged is fundamental; the pictographs are secondary.

Thus we see the League of 50 chiefs laid out in two halves: on the right, one moiety comprises the phratry of the Mohawk-Onondaga-Seneca, the Three Brothers side, who are known as Sires (Uncles), Elder Brothers; and, on the left, the other moiety of the Offspring (Nephews), Cousins, Younger Brothers comprises but the phratry of the Oneida-Cayuga, which is now known as the Four Brothers side, since the younger brothers of the League on the Grand River had under their wing dependent nations including Tuscarora and Delaware, not to mention Saponi, Tutelo, and Nanticoke. Since none of the latter was involved in the founding of the League, they lack the right of condolence.

The rosters of member tribes are, moreover, grouped according to classes or committees of chiefs in accordance with their number and function as follows:

1. Mohawk 3-3-3.
2. Oneida 3-3-3.
3. Onondaga (2-2-2) 6-1-2-3-2.
4. Cayuga 2-3-3-2.
5. Seneca 2-2-2-2.

Note at once that the tribal phratries are composed of a moiety of 3 nations and another of 2, and that precisely 2 and 3 are the predominate units of grouping chiefs in tribal councils. Note also that the Mohawk and Oneida each had three clans of three maternal families each. The other nations, who group their chiefs in multiples of two and three, favor the moiety system.

The arrangement of the pegs on the cane agrees exactly with the space relation charts which Hewitt had from Chief Abram Charles (Hewitt and Fenton, 1945, pp. 304-305). Chief Charles and A. Spragg were neighbors.

The mnemonic can be made to yield something else which it means to Iroquois ritualists. With the help of Chief Charles, Hewitt made a chart which shows how the chiefs variously grouped relate to each other as siblings and cousins. The cousin relation is not apparent in the arrangement of pegs on the cane, although it shows up when laid out in corn. Further field work will clarify the kinship terms as they crop up in the Eulogy. It is not self-evident how, for example, Onondaga 25 is an "uncle" both ways; and the Cayuga have self-reciprocating terms for 33-34 who are "sons to each other."

A. Sprag

(singer of the
Eulogy and
Roll Call)



A. SPRAG

o



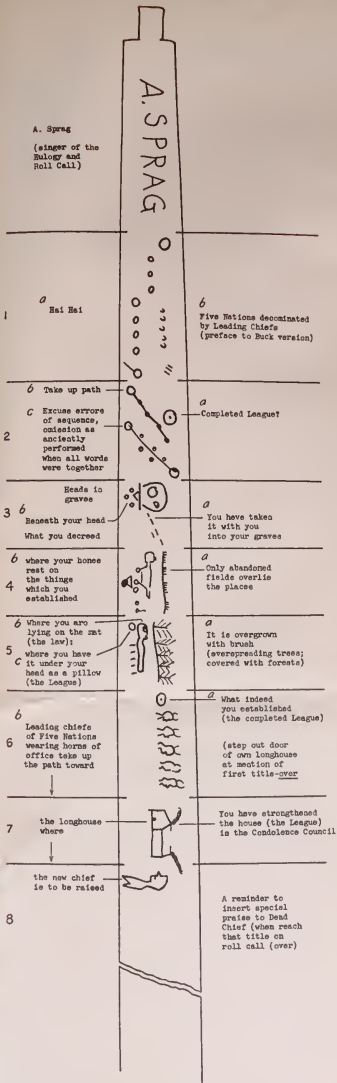


FIG. 2.—Back of the Condolence cane. Introduction to the Eulogy to the Founders of the League.



The chart can be arranged two ways—in order of tribes, as Hewitt had it, or by tribal phratries. In either case, siblings appear vertically; cousins across.

*A.—Relationships and groupings of the federal chiefs by tribes (after Hewitt).
Siblings read vertically; cousins across, within columns.*

I	II	III	IV	V
M	Oe	Oa	C	S
1	10	19-20	33-34	43-44
2 T	11 W	21		
3	12	22	35	45-46
		23	36	
4	13	24	37	47-48
5 W	14 T			
6	15	25	38	49-50
			39	
7	16	26-27	40	
8 B	17 B			
9	18	28	41-42	
		29		
		30		
		31-32		

T—Turtle clan, W—Wolf clan, B—Bear clan.

B.—Relationships and groupings of the federal chiefs into two moieties of tribal phratries as on the cane. Read siblings vertically; cousins across.

Four Brothers (younger)	Three Brothers (elder)
Nephews	Uncles
Offspring	Sires

I M

1

2

3

4

5

6

7

8

9

Four Brothers (younger)
Nephews
Offspring

Three Brothers (elder)
Uncles
Sires

II Oe

10

11

12

13

14

15

16

17

18

III Oa

19-20

21

22

23

24

25

26-27

28

29

30

31-32

IV C

33-34

35

36

37

38

39

40

41-42

V S

43-44

45-46

47-48

49-50

In attempting to relate the roll call to the pictographs, earlier lists of chiefs were examined and tabulated and several manuscript versions of the Eulogy were analyzed. Morgan published repeatedly a list of federal chiefships in Seneca, which he had from Ely S. Parker (Morgan, 1851 (1901, vol. 1, p. 60); 1878, p. 130; 1881, p. 30). The list is divided into classes, approximately the same number as in the above tables, which Morgan thought comprised the chiefs of the original confederating towns. Eighteen classes would mean that many towns. There were 12 such towns in the seventeenth century (Fenton, 1940). The cane calls for 19 groupings, and so do all other lists taken from the Grand River Iroquois. So we are faced with the possibility that Morgan's Seneca informant was mistaken, or that a different tradition had grown up since the division of the League tribes after the American Revolution into an American faction at Onondaga, Tonawanda, Buffalo Creek, Cattaraugus, and Allegheny Reservations on the American side, and the Six Nations on Grand River, Ontario.

Morgan's list does not agree with the order of pictographs on the cane. Such agreement as first appeared seemed to warrant placing the pictographs from the cane alongside Morgan's list in the same table. Results were disappointing and frustrating. Correspondences were fairly close for the Onondaga roster, precise for the Cayuga roster, and the Seneca roster which Morgan's informant knew best begins and ends like the Grand River lists, but the third to sixth Seneca titles are completely inverted. Lloyd, editor of later editions of Morgan's League (vol. 2, p. 212), notes the discrepancies between Morgan's list and that of Hale (1883), and adds remarks and differences based on the list of Chadwick (1897, p. 86).

Hale had his information from Old Smoke Johnson, and the Chadwick list came from Chief Josiah Hill in the orthography which was then in use for the official list at Ohsweken (Chadwick, p. 97). Both lists are the then official Grand River version. There is a still earlier list dated 1847 from Peter Green, about which we have no supporting information. None of these lists quite fits the cane in the middle of the Seneca roster. Even the list of Seneca Chief John A. Gibson (A. A. Goldenweiser, Ms. 1912, pp. 450-462), which otherwise agrees, inverts 45 and 46 in the Seneca roster. So it is likely that the inversions in the official Grand River lists represent the version used by the Three Brothers, whereas the cane was a Cayuga document.

Our problem here is not to find out who was right and who was wrong, but to find a list which fits the cane exactly. For such a list

I turned to the contemporaries and neighbors of A. Spragg among the Lower Cayugas. As is so often the case, the problem solved itself while attempting to solve two others.

In 1945, while editing a paper of Hewitt's on Iroquois mnemonic pictographs which involved identifying a set of similar pictographs which Cayuga Chief Charles had inscribed in a notebook, I found a list that would fit the cane. Hewitt obtained from Chief Charles in 1917 a complete text in Onondaga for the Eulogy, together with an independent list of chiefs whose clan eponyms are differentiated (B.A.E. Mss. Nos. 1281-a, 3558). Like many of his contemporaries on the Six Nations Reserve, Chief Charles used another dialect than the language of his tribe—in this case Onondaga, although he was a Cayuga. In early 1948 a similar identification was made of a list in Mohawk by Seth Newhouse (Fenton, 1949). By typing both lists on opposite sides of a blueprint of the cane, the titles opposite the pegs in sequence, I reached a precise correspondence for the pictographs in Mohawk of 1885 and in Onondaga of 1917.

Title and pictograph.—The meaning of the pictographs depends on how the titles of the 50 founders are interpreted. This was the problem of the lists and how to get correspondence. The interpretation of the titles is subject to the vagaries that attend the meanings of all Iroquois personal names. Names descend in the maternal family, usually skipping a generation, and such names as have become attached to offices, which also descend with the name in the maternal family, acquire special qualities. Many of these titles are descriptive of activities in which the original holder was found engaged when the League was formed. Others were maternal family and clan names then in use. As such they may be shared by the same clan in another tribe, where perhaps the name is not attached to an office. Dialect and folklore have altered the names. They are also subject to continual reinterpretation by native theorists. The roll call of the 50 founders is supposed to be chanted in Mohawk; but it also enumerates rosters of Oneida, Onondaga, Cayuga, and Seneca chiefs whose titles must have originated in the several tribal dialects before the League was formed. Onondaga, Seneca, and Cayuga ritualists render the titles differently. With the titles has descended a body of lore telling what the founders were up to when discovered by Deganawi'dah and Hiawatha. Dialect slowly alters the titles and their meanings, and folklore shifts more rapidly, engendering controversy among tribal ritualists as to just what the titles do mean. Hale quite honestly held that the meanings of many of the names were lost, and that they had in fact become titles. For purposes of describing the Cayuga Con-

dolence cane, it is important first to know how A. Spragg read the pictographs, and next how Chief Charles, the principal whom he represented in singing on the road, interpreted the titles. We are dependent upon Hewitt's notes, and what the writer has learned from contemporary informants.

The Mohawk pictographs.—1. Dekarihokenh (Newhouse, 1885), Dega·iho·'gen' (Charles, 1917), "It separates or divides the matter, of two opinions, offices" (S. Gibson); "Between two statements" (Hale, 1883, pp. 77-78); "Double speech" (Chadwick). The fork, between parallel lines in this pictograph, appears in the Charles lists (Hewitt and Fenton, 1945, p. 307). "Of two opinions" because he opposed the League, but was divided in thought, and was finally appeased by accepting the leading chiefship of the Mohawk (A. General).

2. Ayonhwathah; Hayen'wen'tha', "He who combs" (Morgan); "Seeks the wampum" (Hale); "He sifts with a bark sieve" (Hewitt); "Early riser" (S. Gibson). This culture hero is said to have combed the snakes from the hair of the Onondaga shaman, Thadoda·'ho', straightening his mind. The first approached by Deganawid'ah, first to cooperate, he could not sleep, and rose early and related his experience. They named him "Early riser" or "He who is awake" (General). The pictograph suggests a comb.

3. Sha'dekariwadeh, Sha'dega·ihwa·'de', "Matters of equal height, level words." Five vertical marks, topped by a horizontal, express the idea.

These three Turtle clan chiefs formed the first phratry of founders.

4. Sharenhowaneh, Shaenho·'na', "He the great tree trunk"; "Great tree top" (Hale); "Loftiest tree" (Chadwick). The lofty tree with great branches and bifed roots is depicted.

5. Deyoenhegwenh, Deyon'heh'gwi', "It lives by two life givers" (Hewitt); "Double life" (Hale); "Tenacious of life." This is properly the name of a certain shrub, which has great tenacity of life, according to Chief George Johnson (Hale 1883, p. 155), and possibly this is the plant so carefully illustrated. One of the ferns (*Polystichum acrostichoides* (Michx.) Schott.) has this name. The name is also associated with the cultivated plants, corn particularly.

6. Orenregowah, Oenhe'go·na', "Great white eagle" (Hewitt). Such a bird is depicted. Hale's theory does not apply.

This was the number of the Wolf clan chiefs.

7. Dehennakarineh, Dehenna'ga·i'ne', Tehenna'kariine', "His two horns are moving along, dragging antlers." The pictograph is of an antler, the symbolic horn of office.

8. Rastawenseronthah, Ha'stawen'serońtha', Ha'stawen'sen'tha', "He attaches rattles to it" (Hewitt); "Hanging up rattles" (Morgan); "Puts on the rattles" (Hale); "Holding the rattles" (Chadwick); "Enters with rattle" (S. Gibson). What may be intended for a series of three gourd rattles, one above another, is shown in the pictograph.

9. Shoskoarowaneh, Shosgoharo'waneh, Shosgoha'i'nan, "He the great branch." "Great wood drift" was an interpretation favored by Hale and Hewitt. But the outline of a tree branch appears clearly on all lists of pictographs by Chief Charles, and on the cane.

The latter three founders were of the Bear clan, and complete the roster of Mohawk chiefs.

The Oneida pictographs.—The following chiefs are considered "Offspring" of the first. The reciprocal form "son of each other" (Hale, 1883, p. 156), which would be the case with two intermarrying moieties, appears in some versions, but generally the Oneida are thought to be "Son" and the Mohawk "Father."

10. Odatshedeh, Ho'datche'de', "He bears a quiver" (by a forehead strap), "He carries a fawn skin pouch" (Hewitt); "Bearing a quiver" (Hale). "Carries a quiver" is the usual meaning. The pictograph is a crude representation of the leading Oneida chief who has behind his shoulder what may be interpreted as a quiver with two arrows. Without knowing what was intended the drawing would be of little help. The quiver idea is more prominent in Chief Charles' drawing.

11. Kanongweniyah, Kanon'kwen'yo'don', "Standing ears of corn (corncobs)," "One has set upright several ears of corn" (Hewitt); "Setting up ears of corn in a row" (Hale). Such was the manner of roasting corn (Morgan, 1901, vol. 2, p. 30). The pictograph is an upright ear of corn.

12. Deyohagwendeh, Deyo'ha'gwen'de', "Through the opening" (?). The meaning is uncertain and interpretations vary. Hewitt thought the aperture favored "It has a gullet," or "Difficult swallower," ideas supported by the Charles drawings. "Between the openings (of the forest)," said Simeon Gibson, on the authority of the Deganawi'dah legend which describes this chief as passing without trace through the forest. Morgan supports him. All these versions were discussed in a note by Hale who favored "Open voice." Some sort of aperture is intended by the drawing.

These three were the Wolf clan chiefs, and were the presiding group in the Oneida council.

13. Shononses, Shonon'ses, Shonon'hese', "His house is very long" (Hewitt); "His long house" (Hale). The gable of a house

is prominent in all sets of drawings, sometimes the doorway is shown, and the cane pictograph appears to indicate a type of log house which was formerly constructed on the Grand River with the logs set in vertical position.

14. Dehonareken, Daona'roken''ah, Tehone'oken''ah, De'na·egen''a', "He the small forked root" (Hewitt); "Two branches" (Hale). "Two words (voices) meet" dwenaigen'a (Oa.), dodwennaigen''ah (C.) (S. Gibson).

15. Adyadonneatha, Hadya'tonnen'tha', "He swallows an object (body)" (Hewitt) (Morgan); "He slides himself down" (Hale), or "His body is swaying" (Gibson). A body is prominent in all the drawings and on the cane; Chief Charles favored "swallowing" as the root idea; but the pictograph on the cane stresses a massive body, elbows and knees flexed, faceless, withal like the seventeenth-century war records, illustrated in the Paris Document of 1666 (O'Callaghan, 1849, vol. 1, p. 23).

The second group of Oneida chiefs numbers the last three of the Turtle clan.

16. Adahoneayenh, Dewada·hon'den'yonk, "Two ears hanging," "Pendulous vibrating ears" (as if slit) (S. Gibson). The latter, citing the Deganawi'dah legend, stated that this chief when first seen had enormous ears that had probably been slit for the insertion of feathers, leaves, etc., which on removal left the helix and lobe to hang vibrating. "Moving his ears" is the current interpretation (H. Skye). A large ear is figured.

17. Ronyadashayouh, Ronya'dasha·'yonk (M.), Ganiya'dasha·'yen' (Oa.), "A pouch (of fawn skin) resting" (Hewitt), "Swallows slowly" (S. Gibson), "Easy throat" (Hale). At best obscure, as witness Hale (1883, p. 157). The pouch theory is favored by the drawing on the cane and the Charles drawings.

18. Ronwatshadonhonh, Honwatsaton'honh (M.), Honwatca'don'·hwi' (Oa.), "One has covered him with fog" (Hewitt), "He is covered with mist" (S. Gibson), Hale's "He is buried" is not supported by the drawings, which show a man enshrouded with vapor. The pictograph on the cane shows a face and head having some sort of covering protruding above which does not appear to be mist.

The latter three were the Bear clan chiefs of the Oneida, and as such were cousins to the other six.

This was the roster of the Oneida chiefs.

The Onondaga pictographs.—The next are the "uncles, the name bearers."

19. Adodarhohh, Dehadoda·'ho', Thadoda·'ho', "Ensnarled." Legend gave the Onondaga shaman a head of snakes, which Hayowentha and Deganawi'dah combed free. The pictograph is Medusa-like. This office was formerly in the Bear clan, now Deer.

20. Awennisera, One'sä'hen', Gane'sä'hen', meaning uncertain. Hale's informant favored "Best soil uppermost"; current Onondaga opinion leans to gane'sä·'hen, "On the middle of a field" (Skye). "A tied bundle" (S. Gibson); "In the center of a coil, circle, or stretched hide" (Skye). A circle with a dot in the center was drawn by Chief Charles, but the symbol on the cane suggested a hide (or scalp) stretched on a hoop, with a mark at its center.

The Eulogy text makes this chief "cousin" of 19; Beaver clan claims the office.

21. Dehatkadons, Dehatga'don's, Tha·tga'dons, "He looks both ways (or around), On watch." "Two-sighted" (vigilant) (Chadwick). The pictograph and the name offer a theory for interpreting Janus-faced tobacco pipes from the area (Wardle, 1949). It seems likely that a chief of this name would favor such a pipe, and the theory has ethnological validity, since it is also supported by a Janus-faced cane (pl. 4). Also Beaver clan. Twenty and twenty-one are cousins of nineteen.

22. Yadajiwakenh, Honya'dadji·'wak, Hoya'daji·'wak, "His throat is sour (or black)," or "His sour body" (Skye). "Bitter body" (Morgan), "Bitter throat" (Hale). The pictograph is of no help in deciding the meaning. Small Plover or Snipe clan. This chief and the next two form a phratry.

23. Awekenyat, Awe'gen'hyat, "On the surface of the water." "The end of its journey" (Hale). A water plant grows in strings of vegetation in the creeks at midsummer, its ends trailing on the surface (H. Skye). The figure with knob at top perhaps represents this plant. The office is ascribed to Sharp-shinned Hawk clan ("Ball" by error) (Hewitt).

24. Dehayatgwareh, Dehaya'tgwa·'e', Thayatgwa·'e', "On one side of his leaning body" (?) (Gibson) (Hale), "Both his wings are outspread" (Skye). Hale got both interpretations. The pictograph leans, but more nearly resembles a wing. "Red wings" (Chadwick). Turtle clan.

The first six Onondaga chiefs are "firekeepers," the executive committee of the Confederacy. Hale suggests that they may have been originally of one clan, the Bear, that of their leader.

25. Ononwired(-tonh), Honowie'di', "He conceals, covers it" (Gibson); "He causes it to sink" (H. Skye). Hale supports the

latter. "When they saw him first he was seated by the river casting chips into the water, presumably of beech which would sink to the bottom" (Smoke-Skye). A very important chief constituting a class by himself, he has special responsibilities as keeper of the wampums for the Confederacy. As archivist he was called upon to settle disputes. The Eulogy says of him, "Then he alone was son (offspring of the preceding), He the Great Wolf, on whom their minds depend. . . ." Note that his was the only office in the entire roll call which constituted a class by itself. Naturally the Wolf clan claims the title, and the eponymous animal appears next to the ideograph for the name.

26. Oewenniseroni, Gowennen'shen'donk, Gawenne'sen'donh, "Her voice is hanging," or "Hanging strings" (S. Gibson); "Her voice suspended" (Hale). The meaning is obscure and it has become indeed a title. It is impossible to know what about one-quarter of the titles meant four centuries ago. The inscriber of the cane engraved a stepped character inclined to the right, which also occurs on the Charles drawings. With reference to 25, the Eulogy speaks of this title (26) and (27), "And these were his uncles, the two fireplaces" (clans). Hale (1883, p. 159) says: "The five chiefs who follow probably bore some peculiar political relation to . . . [25]." Deer clan still claims 26 and 27; Eel clan 28-30.

27. Arirhonh, Ha'hi'hon', "He spills, tips it" (Gibson); "Spilled" or "Scattered" (Hale). I am unable to reconcile either interpretation with the foolish-looking character on the cane, unless some idea of mental derangement is intended.

28. Oewayonhnyeanih, Hoyonnyen'ni', "He was made to do it" (H. Skye); "Somebody made it for him" (S. Gibson). The meaning is not clear; Hale found no satisfactory explanation. The ideograph is not self-evident. This office and the next two belong to Eel clan, forming a phratry.

29. (Tho)Sadegwaseh, Shodegwa'sen', or Shodegwa'shon', "He the bruiser," or "He smashes it again" (Gibson); "Bruised repeatedly" (Skye). Cf. 35. "He is bruised" (Hale). The pictograph is a claw hammer of a square-ended type made in the nineteenth century. A ball-headed war club would have been more appropriate and probably would have been illustrated a century earlier. Eel clan.

30. Sakokeaeh, S'hagogen'he', or Shagogen'he', "He saw the people" (Gibson), "He sees her (them) occasionally" (Skye). "He saw them" (Hale). The Iroquois use the third person singular nonmasculine, or "feminine," form to stand for society. "He saw her" is what the illustrator of the cane had in mind, for the pictograph

shows a man facing a woman. This was the number of the Eel clan chiefs.

31. Se'a wi, Ho'sä'ha·'hwi', "He bears aloft a torch" (Gibson); possibly just a title, although the Onondagas sometimes discuss the possibility of Hoda'skwishä'hwi', "He bears a tomahawk in his belt" (H. Skye). Hale (1883, p. 159) agrees. The pictograph is probably intended for a hatchet. Turtle clan had this office in Hale's day. This is the title which determines whether the roll call comprises 49 or 50 founders of the League. The name appears in the first writing of the Abram Charles Eulogy text (p. 16), but at the bottom of the same page occurs, "1923 He says again Ho'sä'hä'hwi' is not a title of a federal chief." Nevertheless, this name is recounted in the roll call, an Onondaga chief has been installed in this title, and in recent times a controversy arose between Onondaga partisans of a full council and Cayuga conservatives or ritual sticklers as to whether this title belonged to a separate individual, or whether, as the Cayugas maintain, the roles of this and the following status were fulfilled by the same person. Andrew Spragg is said to have removed this peg from the cane. Hale seems to have appreciated the situation. The Eulogy text states that in ancient times the two clans had offspring, as if the last two names were additions to the roster. The first was a peace chief, the second a war chief.

32. Skanaawadi, Sganawa·'di', "Across the swamp" (Gibson), "Over the creek" (Hale, Morgan), or "Across the rapid." Both Turtle and Deer clan claim this office. The pictograph favors the interpretation "Across the creek," since the same ideograph is used to represent water as will be found at 43. The text says that this fellow was a great war chief who dispelled the clouds, whose body was riven in twain, being both warrior and councilor; hence the argument that one man occupied both offices. The concept of the split personality is not uncommon in Iroquois culture: the Creator is a good and evil twin, there is a masked spirit with a divided face, 21 was Janus-faced, and 32 is sometimes conceived as a man with tomahawk in one hand and peace belt in the other. One holder of the title went as a peace ambassador to the Huron in 1648 where he committed suicide when his Mohawk allies killed the Huron ambassadors returning from Onondaga (Fenton, 1941, p. 116).

The Cayuga pictographs.—The Eulogy says that the following are "offspring" (of the Mohawk, Onondaga, and Seneca), that they in turn had "laid the brush down" for other tribes—Tuscarora, Tutelo, etc.—who came to them—"several clans combined"—and were adopted. Henceforth their moiety with the Oneida became Four

Brothers. The Cayuga nation was politically the son of the Onondaga nation (Hale, 1883, p. 161).

33. Dekaeayough, Dega'en'yon', Haga'en'yonh, "Wonderer" (S. Gibson); "Man frightened" (Morgan), "Looks both ways" (Hale). "When discovered, he was listening on the ground, and they asked him what he was doing, and he replied, 'I am puzzled, I was listening, and I could hear the weeds growing.'" (H. Skye). This founder seems to have had a touch of natural science curiosity. The ideograph is of no help, unless its author, not knowing English, confused "wonder" and "wander," drawing a meander along a straight line. Bear clan claims the title, which Hale ascribed to Deer. The Eulogy says that this founder and the next were as "sons to each other." The matter of these self-reciprocating kinship terms requires further investigation.

34. Tsinondawerhon, Gedji'nondawe'he', Gadjinon'dawe'he', or Dji'nondawe'ya'. The interpretation of this name is uncertain. "Coming on its knees" (Hale), "Calls a summons" (?) (Gibson), "Manipulating bugs" (Skye). "Old Da'hon, brother of John Smoke (Cayuga), said, 'Gadji'nonda'wehch was the silliest one of the Chiefs. He was fooling with various bugs when they found him.'" (H. Skye). The ideograph is similar to 33. "Ball" or Hawk clan claims it. The two—33 and 34—as "sons to each other" preside as firekeepers over the Cayuga tribal council. As members of clans in opposite moieties, which spatial arrangement is indicated laterally when the relationship pattern is expressed in kernels of corn at rehearsals, they should be "cousins."

35. Kadagwarasonh, Gadagwa'dji', or Gadagwa'se', "Bruised, mashed, or softened" (S. Gibson). Hale also noted the similarity of this name to 29 (Onondaga). The pictograph may represent a ball-headed war club. Bear clan claims this and the following title; 35 through 37 form a phratry.

36. Soyowes, Shoyon'we's (Oa.), Shoyon'wes (C.), "His guts are long" (S. Gibson); "He has a long wampum belt" (Hale, 1883, p. 161). The pictograph favors intestines.

37. Watyaseronneh, Hadya'sen'ne' (Oa.), Hadya't'rone', or Haja't'rone' (C.), "He repeats (rehearses) it" (Gibson); "He puts one on another, piles it on" (Hale). The pictograph suggests stacked dishes of elm bark. Turtle clan. This was the number of the phratry, the second Cayuga class.

The next phratry of three chiefs, of the opposite moiety, are called younger brothers. The preceding was known as the Turtle moiety, the next as the Wolf.

38. Deyohronyonkoh, Deyoen'hyon'go' (Oa.), or Thowen'hyon'go', Deyoron'hyon'go' (C.), "Reaches the sky." A line is drawn to the celestial dome. Heron clan now has this title, although Charles and Hale assign it to Wolf.

39. Deyothorehgwen, Deyot'howe'gwi' (Oa.), Deyot'oweh'gwen' (C.), "Doubly cold." Duality is again expressed in a double-lensed ideograph. Wolf clan.

40. Dawenhethon, Diyawen'het'hon' (Oa.), Deyonhwe't'on (C.), "Two things happen" (double event) (Gibson); Thaowethon, "Mossy place" (Hale). The pictograph remains obscure. The title has been transferred from Wolf to Snipe clan, since Hale's day.

Three is the number of colleagues in the third Cayuga group, but the next, 41, belongs to the same phratry. He and his colleague, 42, who controls the second group, are of opposite moieties and therefore "cousins." They two are the "doorkeepers" of the Cayuga council.

41. Wadondaherha, Hadonda'he'ha' (Oa.), Hadonda'he'hä' (C.), "He commences it" (Gibson), "He shoulders a log" (H. Skye), an interpretation which is sustained by the pictograph of a man supporting a round object on one shoulder. "Crowding himself in" (Hale). Snipe clan.

42. Deskae, Desga'he', Desga'he', "He does something" (?); Heskahē, "Resting on it" (Hale). It is not clear what this title means or what the founder did. The present holder of the title, Chief Alex General of the Upper Cayuga band at Sour Springs, holds that the name means "More than eleven." He is of the Bear clan. The pictograph remains obscure.

This ends the Cayuga roster.

From here on the singer looks toward the end of the cane.

The Seneca pictographs.—"And then his father's clansmen," says the Eulogy. The Seneca as brothers of the Mohawk and Onondaga are uncles to the Cayuga, their offspring.

43. Skanyadariyoh, Skanyadai'yo' (Oa.), Ganioda'yo' (S.), "Handsome lake," literally, "It is a very large lake." The pictograph stands for water. Turtle clan.

The Seneca councilors are linked in pairs of opposite moieties. Each member of the four pairs calls his colleague by the reciprocal, cousin.

44. Shadekaronyes, Sha'degaen'hyes (Oa.), Tca'dage'onye's (S.), "Skies of equal length," "Level heavens" (Morgan). The pictograph is two curved lines of corresponding length and arc, representing the celestial dome. This founder was leader of the second great division of the Senecas, and Snipe clan has consistently held the title both in

Canada and in New York. The Senecas have preserved a moiety system from early times.

45. Shakenjohwaneh, Shagen'djo·'wane' (Oa.), S'hagen'djo·na' (Oa.), S'agen'dzo·wa·' (S.), "Great forehead," "He of the large forehead." A full face with large brow is depicted. This is the Hawk clan chief. Hale (1883, pp. 162-163) remarked the confusion which has arisen between Morgan's and his own lists as to the roll call for the second and third classes. We follow Chief Charles because his list fits the cane.

46. Kanokareh, Ga'no·'gai' (Oa.), ga'nogai' (S.). No satisfactory translation. The pictograph suggests the homophonic word ga'non (S.), "arrow." Tonawanda Seneca lore gives "chewer, biter, killer" (Y. Spring); Hale (1883, p. 163) "threatened." Turtle clan.

47. Deshanyenah, Nis'hanye'nen't, Nis'hanyenen'nha' (Oa.), Ni'shanye·nen't (S.), "Falling day" (Morgan), "The day fell down" (Hale). "Falling day" to the Tonawanda Senecas. Snipe clan. I see no resemblance to this idea in the pictograph.

48. Shodyenawat, Sadye'nawat, "He grasps it" (S. Gibson), "Withheld" (Hale); Sadjen'nowa's (S.), "Helper" (Spring), "Assistant" (Morgan). The pictograph supports the Grand River version, "grasper," showing a hand, bear paw, or turtle foot having five claws or fingers. Bear clan.

The League was gradually extended, and the last two Seneca chiefs held out for some time. The Eulogy pays them special attention: "So it befell in ancient times that they considered extending the framework (of the League) by adding great dark roof poles, and selecting two guardians of the great dark doorway . . ." (which stood to the west) the following:

49. Kanonkeridawih (M.), Ganon'gei'da·'wi' (Oa.), Ganonhgi'dawih' (S.), "Hair singed off," "It broils." Snipe clan; Hale found Bear, but noted Morgan gave Snipe. The pictograph shows the open doorway, but nothing stands for the title, except possibly a spot to represent fire.

50. Deyohninhohhakarawenh (M.), Deyonin'hoga·'wen' (Oa.), Donihogä·'wen' (S.), "It keeps the doorway open"; literally, "It holds up the door-flap," referring to the ancient bark or skin door hinged at its top in the longhouse of the League (Hewitt). "Open door" is the simple rendering of Morgan, Hale, and H. Skye. Wolf clan. The symbol is a doorway and house gable.

"This is the roll call of the founders of the Great Peace; Hail Grandsires. . . !"

The Eulogy ends on a note of humility, of regret that the present generation is losing the old ways, and is no longer able to perform the ritual in the manner of the founders. Hale thought that this dejection of mind was over the loss of a chief whose successor they were about to install (Hale, 1833, p. 165).

EVIDENCE OF AGE

Ethnological investigation has developed that the age of the specimen does not carry it back to pre-Columbian times. This does not mean, however, that the specimen may not be an important one or that the ideas which it memorializes may not have ancient cultural roots. The first fact that struck us about the Cranbrook Condolence cane, the subject of this study, was the apparent disfigurement at one end and the information that this was ". . . owing to an umbrella handle having once been fitted to the stick by a former owner, A. Spragge, Grand River Reserve" (Chandler and Hatt to Fenton, personal communication). Although Yankee Spring, my Seneca informant, had asserted that the cane was surmounted by an eagle head, Cayuga chiefs who had seen it more often held out for the curved handle which they likened to a sword guard. Recent reconstructions at Grand River have such a handle. Surely if there was any analogy drawn between a sword and the appearance of this record stick in the minds of Iroquois Indians there was something modern about it.

The absence of the Sixth Nation, the Tuscarora, from the record can be interpreted two ways. The Tuscarora became part of the League in the second decade of the eighteenth century, but they remained second-class citizens, never enjoying the rite of *Hai Hai*, and, although represented, never voted in the council of the League. On the basis that they are not listed on the cane, we might say that the cane antedates 1710; but since we know the above, this argument is irrelevant to dating the specimen. It simply does not have to be that old.

Had the cane dated from the beginnings of the League, as some ethnologists at first thought, it would have shown a good deal of handling and it would have acquired some patina. While the relation of patina to age is difficult to establish, it is worth while noting that early nineteenth-century specimens of known date show more or less patina. They look older than the Iroquois cane. On subjective grounds the Iroquois stick may not be older than 1850, but patina remains an unsatisfactory criterion.

The mnemonic which the cane carries is probably older than the pictographs. There were canes with pegs only, and the same mnemonic



FOUR BROTHERS SIDE
OFFSPRING (NEPHEWS)

THREE BROTHERS SIDE
SIRE (UNCLES)

MOHAWK

Sevhouse 1887 M.

Charles 1917 G.

Deharthohseh

1 Deah' tho' gah'

Ayohwathah

2 Ayaah' wath' the'

Shahkar'wah

3 Sha' daga' thwa' da'

Sharehbowah

4 Shaeha' ba'

Dyohwahgweh

5 Dyaoh' wa' gwi'

Oreuregwah

6 Oeha' go' ah'

Dehahmaharinh

7 Dehama' ge' i' de'

Deheweherohah

8 De' atama' aea' the'

Shohkourwah

9 Shohgaha' than

ONEIDA

Odatshedah 10

10 Oe' datcha' da'

Kanongwenyah 11

11 Kanoh' gwa' yo' doh'

Dayohagweh 12

12 Dyaoh' wa' gwa' da'

Ehohonee 13

13 Ehoon' aea

Dehoharoken 14

14 De' ah' agha' a'

Adyahoneetha 15

15 Aya' h' doonah' the'

Adahondagweh 16

16 Dewada' hoh' den' yonk

Eoyohashayoh 17

17 Eoyah' ashay' yoh'

Konwatahadonhoh 18

18 Konwata' doh' hoh'

Adoharohoh

19 Dehadoda' hoh'

Areniaera

20 Aeh' aeh' hoh'

Dehahadone

21 Dehahga' hoh' a'

Tedahjinhoh

22 Tahya' hadji' wa'

Arehograt

23 Aeh' agha' hrat

Dehahagwah

24 Dehahga' tgha' a'

Onowireh- (-toth)

25 Onowia' di'

Deveniaeromi

26 Deweha' agha' hoh'

Arirhoh

27 Aeh' hoh' hoh'

Devyohagweh

28 Dyaoh' agha' hoh'

(Tho) Gahagweh

29 Gahagwe' agha'

Shohagweh

30 Sh' hahagwe' hoh'

De a wi

31 De' ad' hoh' wi'

Shahawadi

32 Shahawa' di'

ONONDAGA

CAYUGA

Dehahagweh 33

33 Deah' wa' yon'

Tahohdeverton 34

34 Tahji' doonawa' hoh'

Eahagweh 35

35 Eahagwe' di'

Eyohweh 36

36 Eyah' wa'

Wahagweh 37

37 Wahya' agha' hoh'

Dyohroghweh 38

38 Dyaoh' hoh' go'

Dyohroghweh 39

39 Dyaoh' hoh' gwi'

Dehaharohoh 40

40 Dyaoh' hoh' hoh'

Madonsharha 41

41 Madoda' hoh' hoh'

De a e 42

42 Deah' hoh'

SENECA

Shahagweh 43

43 Shahagwe' hoh'

Shahagweh 44

44 Sha' daga' hoh'

Shahagweh 45

45 Shahagwe' hoh' wa'

Shahagweh 46

46 Sha' go' gwi'

Shahagweh 47

47 Sha' hahga' hoh' t'

Shahagweh 48

48 Shaga' hoh'

Shahagweh 49

49 Shaga' gwi' da' wi'

Dyohroghweh 50

50 Dyaoh' hoh' wa'

FIG. 3.—Front of the Condensé cane. The roll call of the Founders of the League.



is laid out in kernels of corn. The pictographs, with certain exceptions which resemble early treaty signatures and some war records of the seventeenth century, appear modern and give evidence of having been worked over and embellished in later times. Certain of them represent objects of recent historic introduction, a type of log house built at Grand River formerly (13), the nineteenth-century claw hammer (29). They are in character with the drawings of Chief Abram Charles and could almost have been made under his direction.

Chief Charles was an advocate for the position that there were only 49 chiefs, that the Onondagas had 14 offices held by 13 persons. So was Andrew Spragg. The cane appears to have been equipped with 50 pegs, including 14 for the Onondagas. The last of these has been cut off, which means that the specimen antedates this controversy, for which we may take the year 1923, when it is first mentioned in Hewitt's notes.

Besides the alteration of the pegs, the cane shows the marks of successive owners. The possibility has been indicated that the pictographs were added to and altered or worked over by several persons who must have had the specimen in their possession for some time, probably as keepers. A. Spragg went so far as to inscribe his name, and we know that he was its last custodian. John Smoke knew of three holders—Ganawado who made it, Sheriff Billy Wage, and Spragg. This takes it back to about 1850, with but one weak link in the chain. Hale, who saw Billy Wage in action in the summer of 1883, does not say that he carried a cane, nor does he describe the staff carried by Silversmith who took over the role inside the long-house. Allowing 20 years apiece for each of the holders (and this is generous) we reach the year 1860 as the probable date of its manufacture. This would be in the second or third generation on Grand River.

Other evidence from related specimens shows that it combined several ancient ideas. Counting with kernels of corn in diagrams permeates Iroquois ceremonialism. The use of canes as symbols of age status has also been remarked. And we have shown that similar tallies and pictographs had earlier cultural beginnings. What we have then in the present specimen is a synthesis of several cultural traits which have long historic roots in the past.

CONCLUSION

In this study of the Condolence cane in the Cranbrook Institute we have tried to show its provenience, to date it within reasonable probability, to uncover its cultural roots, to explain its function

within the Condolence Council, and to interpret its symbolism. It is certain that Andrew Spragg was a late holder of the ritual and keeper of the cane, which belonged in a way to all the Cayugas. Made sometime after the middle of the nineteenth century, probably about 1860, its use was confined to the Lower Cayuga band on the Grand River. Alterations in the specimen reflect local opinion on the Six Nations Reserve as to how many federal chiefs founded the League, how they were arranged, and the order of the roll call. Unquestionably it was devised on an ancient mnemonic design in order to preserve the memory of the Eulogy chant and roll call and to support the performance of the Condolence Council for installing new chiefs after settlement on the Grand River. Although it is now a sacred relic, and it has been reproduced once more by the Cayugas, the Cranbrook specimen does not antedate the American Revolution and the dissolution of the League in New York. It cannot be referred, therefore, to the period of the founding of the League.

The investigation has forced us to study the institution of the Condolence Council. It has succeeded in unraveling the meaning of the pictographs and it has demonstrated how they relate to two local versions of the Eulogy chant—Newhouse (1885) and Charles (1917). It poses certain problems of kinship for future field work, since we now have before us the complete organization chart of the government of the Iroquois Confederacy, which was, perhaps, the classic example of the kinship state.

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PLATES



1. GRAVE OF PATTERSON SPRAGUE IN LOWER CAYUGA CEMETERY, SIX NATIONS RESERVE

(R. T. Hatt photograph.)



2. A LOG HOUSE AT SANDY'S CORNERS, SIX NATIONS RESERVE, ONCE OCCUPIED BY ANDREW SPRAGG

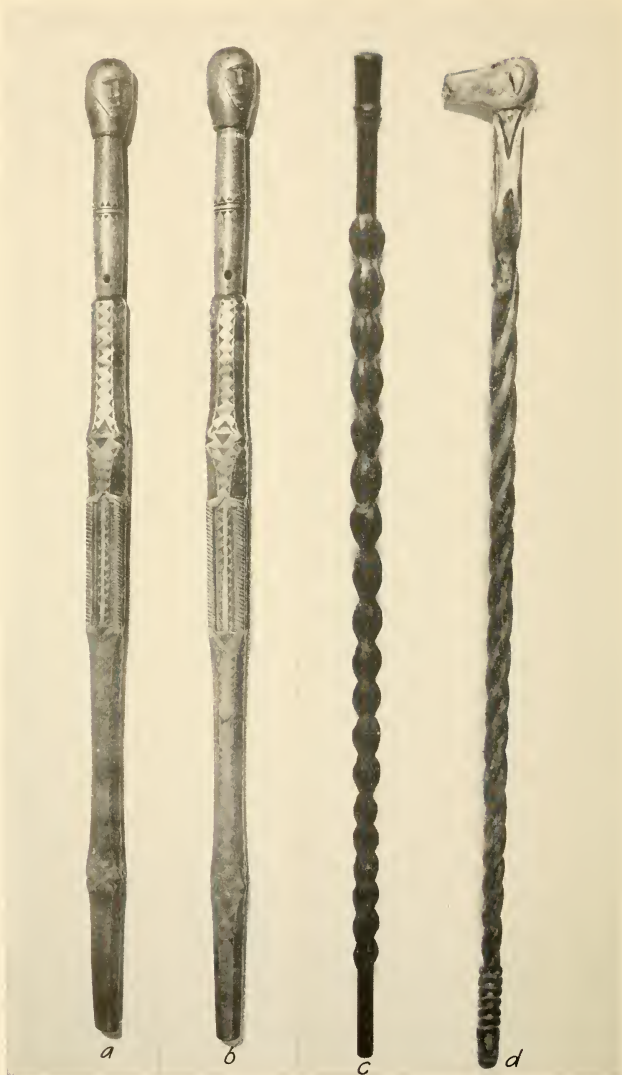


THE ROLL CALL OF THE IROQUOIS CHIEFS
The Cayuga Condolence cane of Andrew Spragg.



CHIEF'S CANES FROM THE SIX NATIONS RESERVE

(National Museum of Canada photograph.)



CHIEF'S CANES FROM CANADA

a and *b*, Janus-faced cane from Chiefswood collection (Royal Ontario Museum of Archaeology); two sides showing face. *c* and *d*, Canes from the Huron or Iroquois of eastern Canada (Quebec Provincial Museum).



CANES WITH CLAN EFFIGIES, AND A FALSE-FACE

a, Bear effigy; *b*, Wolf effigy; *c*, False-face or masker; *d*, the cane of the 12th Onondaga chief S'agogen'he' (No. 30 on the cane). (Milwaukee Public Museum photographs.)



1. DETAIL OF CLAN EFFIGIES ON PLATE 5

a, Bear; *b*, Wolf.

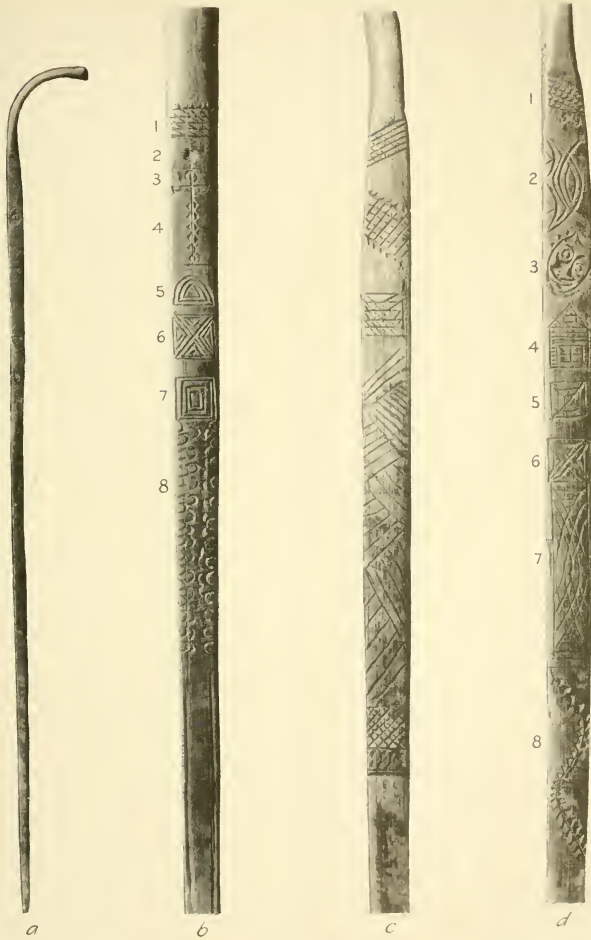
(Milwaukee Public Museum photographs.)



2. DETAIL OF CLAN EFFIGIES ON PLATE 5

a, False-face; *b*, Wolf.

(Milwaukee Public Museum photographs.)



CANE USED AT A CHIEF'S WAKE, SIX NATIONS RESERVE

a, Over-all view of cane (collected by J. N. B. Hewitt, 1916; U.S.N.M. No. 384288, Division of Ethnology); *b*, front view detail: notice of death and the funeral; *c*, right side detail: wampum belts of notification; *d*, left side detail: passage of the soul to the hereafter.



PICTORIAL RECORD STICK OF THE SENECA PROPHET'S REVELATION
(Milwaukee Public Museum photograph.)

16 (ms)

(Ka nyu he ha ku.)

- De ka ri oh henk, 1
- A yon h wa thak, 2
- sha de ka ri na del. 3

Ka nyu he ha ku.
 1
 2
 3

- Sha ren ho na neh, 4
- De yon he gwentk, 5
- O ren se go wali. 6

Sha ren ho na neh.
 4
 5
 6

- De he ni na ka ri neh 7
- ka sta nen se rent hak. 8
- Sho sho a re na neh. 9

O ren se go wali.
 7
 8
 9
 10
 11
 12
 13
 14
 15

2

(O m n yoh de a la.)

- 10 O dats he del,
- 11 Ka non gwen i yah,
- 12 De yo ha gwen del.
- 13 Sho non ses,
- 14 De ho na re hen,
- 15 I dyu don nea tha.

SETH NEWHOUSE'S ROLL OF THE CHIEFS (CA. 1885)

The Mohawk and Oneida rosters with mnemonic.

- 16 ⁶ I da hon deu yenh,
 17 Ko nyu das ha youh.
 18 Ron wats lu don honh.

(Onon³ da ge² ba ka.)
 7 e I do dar honh, 19

e I wen ni se ru, 20.

De hat hu dons, 21

Ya dajji wa kenh, 22

• Ball. I we ken gat, 23

De ha yat gwa reh, 24

⁸ Onon wi reh, 25

⁹ Oe wen ni se ron ni, 26

e I riv honh. 27

¹⁰ Oe wa yonh nyca nih, 28

~~Thom~~ de gwa seti, 29. Eel

Su ho ke~~ah~~. 30

31 ~~Ha wi, Taitai~~

32 Sha naa wa di.

¹² K'ora youk gon hah ha.)
 K'ha ea youk, 33 Deer.

~~x~~ Tsi non da wer hon. 34 Deer.

⁷ ha da gwatpu sonk, 35 Bear

So you wes, 36

Tortoise Wu tya se ron neh. 37

¹⁴ De yoh ron yon koh, 38 Wolf

De yot ho reh gwenh, 39 Wolf.

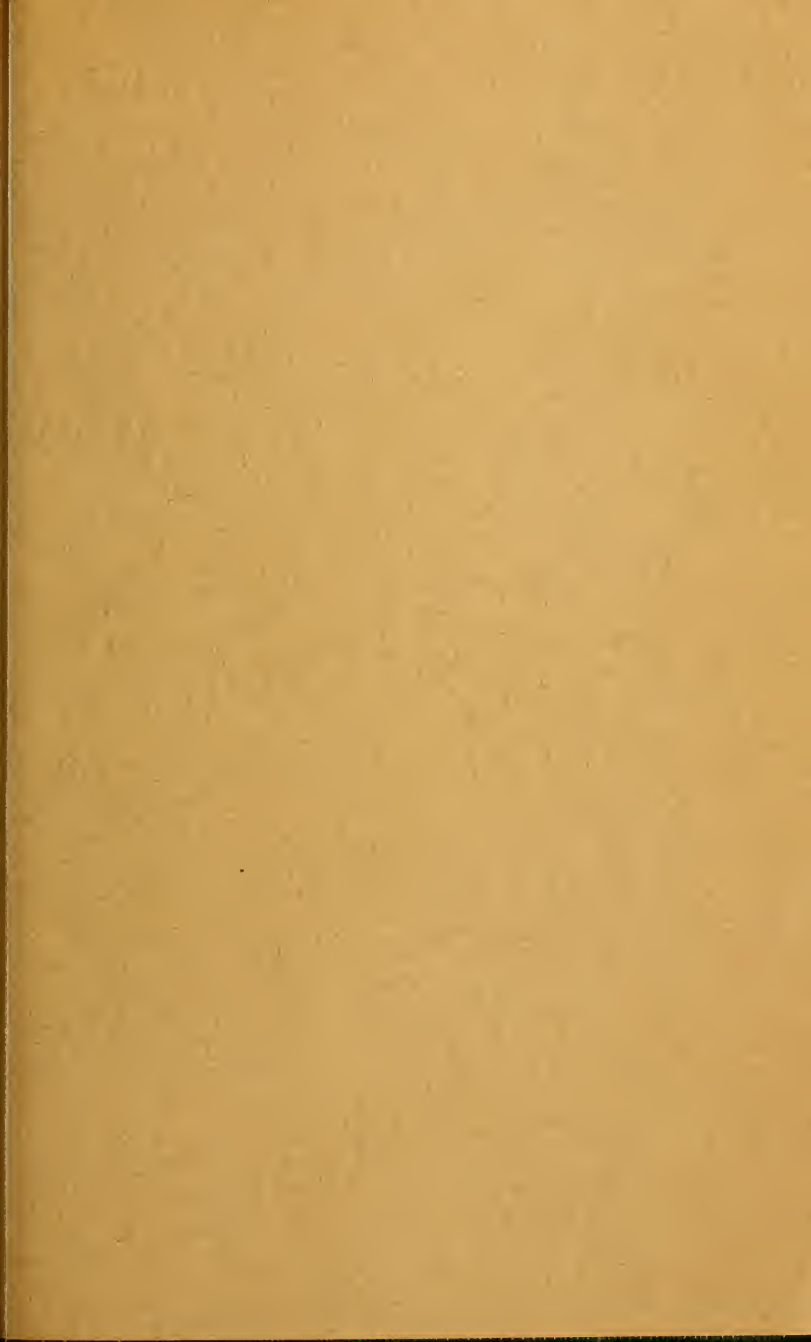
~~Snipe~~ Da wen het hon. 40

¹⁵ Wa don da herha, 41 Snipe

Des ka e. 42

(⁵ Jo non do wa ka.)

- ¹⁶
 (a) *Sha nya dāri yoh,* 43
 2 *Sha de ka ron yēs,* 44
 4 *Sha ken joh wa neh,* 45
 Tortoise ~~#~~ *ka no ka reh,* 46
 Des *ka ge nah,* 47
Sho dya na wat, 48
 { *Ka non he rik da wih,* } 49
 (*De yoh nin hoh hu ka'ra wenh.*) 50





SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 16

THE FORMS OF THE BLACK HAWK-EAGLE

(WITH ONE PLATE)

BY
HERBERT FRIEDMANN
Curator, Division of Birds, U. S. National Museum



(PUBLICATION 4013)

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THE FORMS OF THE BLACK HAWK-EAGLE

BY HERBERT FRIEDMANN

Curator, Division of Birds, U. S. National Museum

(WITH ONE PLATE)

The black hawk-eagle, *Spizaetus tyrannus* (Wied), has always been considered as a species with no geographic races, and, indeed, I so assumed it to be a number of years ago when working on this genus for the eleventh volume of Ridgway's "Birds of North and Middle America." However, recently I have had occasion to examine far more extensive material than was formerly available, and I find, quite contrary to my earlier opinion, that there are two morphologically separable geographic units in the species. The type of *tyrannus* came from Ilha do Chave, below Quartel dos Arcos, Rio Belmonte, Bahia, Brazil, and the only other names applied to the species are likewise based on eastern and southeastern Brazilian birds—*Harpyia braccata* Spix (*Avium species novae* . . . vol. 1, p. 7, pl. 3, 1824 (=1825)) from São Paulo, Brazil, and *Spizaetus spixii* Des Murs (*Rev. Zool.*, vol. 10, p. 325, 1847) which is merely a new name for *H. braccata* Spix.

Birds from México and Central America, and from northern and western South America, south to Pará, the Amazon Valley, and western Brazil (Rio Purús and Rio Juruá and Mato Grosso) and Bolivia are different from specimens from Bahia, Espírito Santo, Rio de Janeiro, Santa Catharina, Minas Gerais and São Paulo in eastern and southeastern Brazil, and for them is proposed the name

Spizaetus tyrannus serus, new subspecies

Type.—U.S.N.M. No. 206391, ad. ♂, collected at Río Indio, near Gatún, Canal Zone, Panamá, March 4, 1911, by E. A. Goldman (orig. No. 13928).

Subspecific characters.—Similar to the nominate race but with the flanks and thighs more heavily marked with white cross bars, and with the under wing coverts much more whitish, less blackish; these feathers white, rather sparingly marked with blackish in *serus*, and almost wholly black in *tyrannus*. Size of *serus* averaging smaller than the nominate race.

Description of type.—All feathered parts of top of head black, the feathers of the crown and the occipital crest with their basal half or more pure white, much of this color usually showing through among the overlapping feathers; scapulars, interscapulars, back, upper wing coverts black; remiges externally fuscous black to black, crossed by five or six dull fuscous bars about equally spaced, the bars being slightly narrower than the black interspaces and becoming mottled or edged with whitish on the inner margin of the inner webs, these bars grayish white on the under surface of the remiges; rump black, the upper tail coverts black, each feather crossed by two or three narrow white bars which are slightly mottled with brownish gray, and also narrowly tipped with white; rectrices black paling to whitish basally and crossed by four broad bands of deep ashy gray mottled with pale fuscous and whitish, and narrowly tipped with whitish; all the tail bands white on the under surface; chin black, the feathers white basally; feathered portions of lower cheeks and auriculars, throat, breast, sides, and upper abdomen black; lower abdomen and flanks black spotted sparingly with narrow, semitransverse white flecks; thighs black broadly barred with white, the black interspaces somewhat broader than the white bars (in typical *tyrannus* these white bars are very narrow lines); under tail coverts like the thighs and flanks but with the white bars still broader and more broadly spaced; under wing coverts mostly white broadly barred with black, the outer, greater, under primary coverts white with only a sub-terminal and a subbasal black bar (in typical *tyrannus* the under wing coverts are black with sparse and narrow white barrings).

Young birds of both races tend to have more white on the under wing coverts and tibiae than do the adults, but even here the difference between comparable birds of the two subspecies is striking.

Measurements of type.—Wing 381; tail 309.8; culmen from cere 27.5; tarsus 81; middle toe without claw 44 mm.

In size *S. t. serus* averages smaller than *S. t. tyrannus*; thus males of *serus* have wing lengths of 354-394 (379.5 mm.) and tails 291.1-325 (309.8) in length as opposed to wing lengths of 362-422 (398.3 mm.) and tail lengths of 365-367 (366 mm.) in the nominate race; females of *serus* have wing lengths of 353-444.5 (412.5 mm.) and tail lengths of 289-386 (337 mm.), while females of *tyrannus* have wings of 428-460 (443.7 mm.) and tails measuring 370-405 (388.8 mm.)

Range.—Resident in heavily forested areas of the tropical zone from southern México (Oaxaca, Chiapas, San Luis Potosí, Puebla, Veracruz, Campeche, and Yucatán) south through Guatemala, Hon-

duras, British Honduras, Nicaragua, El Salvador, Costa Rica, and Panamá to Colombia, Ecuador, Perú, Venezuela, Trinidad, the Guianas, northern and western Brazil (Pará, the Amazon Valley, Rio Purús, Rio Juruá and Mato Grosso), to Bolivia (Santa Cruz).

The nominate form appears to be restricted to eastern Brazil (Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro, Santa Catharina, and São Paulo) and possibly ranges to northeastern Argentina (Misiones). The species has been recorded once from Paraguay (Sapucai), but, in the absence of material from that country, it is not possible to say which race may have been involved.

Material examined.—Thanks to the cooperation of the authorities of the Chicago Natural History Museum and the Museum of Comparative Zoölogy, I have been able to add to the material in Washington and have thus personally studied 30 specimens. In addition to these, I am able to include here notes on a still larger number of specimens in other museums, kindly made for me by Dr. Pinto on the birds in the museum at São Paulo, Brazil; by Mr. Peters on additional specimens in the Museum of Comparative Zoölogy, Cambridge; by Mr. Todd on those in the Carnegie Museum, Pittsburgh; by Mr. deSchauensee on the birds in the Academy of Natural Sciences of Philadelphia; and by Dr. Zimmer on those in the American Museum of Natural History, New York. The combined material may be listed as follows:

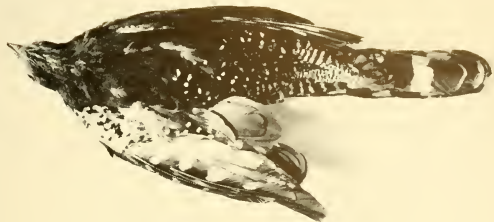
Spizaetus t. tyrannus.—Eastern and southeastern Brazil (Bahia south to São Paulo) 20 (including the type); "South America" 2; total 22 specimens.

Spizaetus t. serus.—Mexico 8; Guatemala 1; British Honduras 1; Honduras 1; Nicaragua 1; Costa Rica 4; Panamá 10 (including the type); Colombia 4; Venezuela 1; Dutch Guiana 6; Ecuador 2; northern and western Brazil (Pará, the Amazon Valley, Rio Purús and Rio Juruá, Mato Grosso) 9; Bolivia 2; total 50 specimens.

Remarks.—The two species of *Spizaetus* inhabiting the American Tropics each divide into two races, but the geographic pattern of this division is quite dissimilar in the two. In the case of the present species the data, still incomplete for much of the interior of Brazil (states of Maranhão, Ceará, Parahyba, Goyaz, southern Pará, and Mato Grosso), indicate that the nominate form is largely a bird of the coastal or semicoastal forested areas from Bahia southward to São Paulo, and that the species apparently does not occur in the adjacent (to the west) extensive areas of "campos" country of the "Planalto" and of the still farther inland grasslands stretching from south of the Amazon forest to parts of northern and eastern Bolivia.

The race *serus* ranges from the Amazonian forest and its outliers (from Pará in the east, and in the west from the Rio Purús and Rio Juruá, from Mato Grosso (São Luiz de Cáceres) and from Santa Cruz in Bolivia) northward to Perú, Ecuador, Colombia, Surinam, Venezuela, Central America, and México.

In *Spizaetus ornatus*, which, as a species, seems to have a range geographically and ecologically very similar to that of *S. tyrannus*, the northern race *vicarius* occurs from southern México, south across Central America to Colombia west of the eastern Andes, and western Ecuador, possibly to Perú, while typical *ornatus* is found from Venezuela and the Guianas southward across Brazil to Bolivia and Paraguay. In *Spizaetus ornatus* it looks as though the Andes constituted a possible barrier between the component forms, whereas in *S. tyrannus* this is not the case.



BLACK HAWK-EAGLE

1, *Spizocelus tyrannus tyrannus* from Joinville, eastern Brazil; 2, *S. l. serus* from Chiapas, Mexico



SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 111, NUMBER 17

Roebbling Fund

PERIODIC INFLUENCES
ON WASHINGTON AND NEW YORK
WEATHER OF 1949 AND 1950

BY

C. G. ABBOT

Research Associate, Smithsonian Institution



(PUBLICATION 4015)

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PERIODIC INFLUENCES ON WASHINGTON AND NEW YORK WEATHER OF 1949 AND 1950

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A. PRECIPITATION AT WASHINGTON

In Smithsonian Miscellaneous Collections,¹ I have traced the influence of a cycle of 27.0074 days on Washington precipitation. This cycle is thought to be associated with the rotation period of the sun. Dates were assigned when it was expected that, on the whole, greater average precipitation would fall in Washington than on the average of all other dates. In 1949, for the sixteenth consecutive year, this proved to be so. The ratio of average daily precipitation on preferred dates of 1949 to average daily precipitation on all other dates was 1.56. Basic statistical study of the years 1924 to 1941, inclusive, indicated the expected ratio to be 1.42. The average ratio for 16 years ending with 1949 is 1.47. In detail the year 1949 yielded the following values:

TABLE I.—*Statistics of Washington precipitation, 1949*
(Values in inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average } Pfd.	0.219	0.143	0.207	0.098	0.229	0.044	0.070	0.269	0.209	0.024	0.025	0.067	0.137
per day } All other	0.118	0.090	0.053	0.040	0.139	0.077	0.220	0.000	0.039	0.0161	0.025	0.043	0.083
Ratio $\frac{\text{Pfd.}}{\text{Other}}$	1.86	1.59	3.90	2.45	1.65	0.57	0.32	*	5.40	0.15	1.00	1.57	1.56
Total ppt.	5.08	3.21	3.96	2.01	5.65	1.85	4.57	4.57	3.55	3.21	0.74	1.72	40.12
Normal ppt.	3.55	3.27	3.75	3.27	3.70	4.13	4.71	4.01	3.24	2.84	2.37	3.32	42.46
Percent of normal	1.43	98	106	61	153	45	97	114	110	113	31	52	94

* Infinitely large.

Preferred days of 1949 had a higher average precipitation than all other days in all months but June, July, and October.²

¹ Smithsonian Misc. Coll., vol. 104, Nos. 3 and 5, 1944; vol. 110, No. 4, 1948; vol. 111, No. 5, 1949.

² In November recorded rainfall averaged the same in both groups, but traces of rain fell on 4 preferred days and on only 3 other days. During July and August rain fell copiously in northern Washington, and nearby, on preferred days when none was recorded at the Weather Bureau.

Table 2 gives the dates for 1950 when the average daily precipitation in Washington is expected to exceed the average daily precipitation in this city on all other days. In the first column are given in Roman numerals the day numbers of the 27-day cycle when higher

TABLE 2.—*Predicted dates for the year 1950 when average daily precipitation should exceed average daily precipitation of all other dates of the year 1950 in Washington, D. C.*

"Preferred" cycle places	Jan.	Feb.	Mar.	Apr.	May	June
I	11	7	6	2, 29	26	22
II	12	8	7	3, 30	27	23
III	13	9	8	4	1, 28	24
IV	14	10	9	5	2, 29	25
V	15	11	10	6	3, 30	26
XII	22	18	17	13	10	6
XIII	23	19	18	14	11	7
XV	25	21	20	16	13	9
XVII	27	23	22	18	15	11
XVIII	1, 28	24	23	19	16	12
XXII	5	1, 28	27	23	20	16
XXVI	9	5	4, 31	27	24	20
XXVII	10	6	5	1, 28	25	21

"Preferred" cycle places	July	Aug.	Sept.	Oct.	Nov.	Dec.
I	19	15	11	8	4	1, 28
II	20	16	12	9	5	2, 29
III	21	17	13	10	6	3, 30
IV	22	18	14	11	7	4, 31
V	23	19	15	12	8	5
XII	3, 30	26	22	19	15	12
XIII	4, 31	27	23	20	16	13
XV	6	2, 29	25	22	18	15
XVII	8	4, 31	26	23	19	16
XVIII	9	5	1, 28	25	21	18
XXII	13	9	5	2, 29	25	22
XXVI	17	13	9	6	2, 29	26
XXVII	18	14	10	7	3, 30	27

precipitation is expected. These values arise from the statistical study, 1924 to 1941, above mentioned. The other columns give the actual days in the 12 months of 1950 when these Roman cycle dates will occur. In other words the remaining columns give the "preferred" dates for 1950. While it is expected that for the entire year 1950 the "preferred" dates will yield higher average precipitation than all others, and even that this will be so for most of the individual months of 1950, the probability that any individual "preferred" day will yield

precipitation is scarcely above 50-50. Recent press accounts of surprising accuracy in these predictions for individual days of past years refer merely to lucky happenings.

The basic statistical tabulation from 1924 to 1941, to which I referred above, and on which table 2 is based, began January 1, 1924. The length deduced for the cycle is 27.0074 days. In 352 cycles of this length there are 9506.6048 days. In the years 1924 to 1949, inclusive, there were 9497 days. Hence the Roman cycle date I falls on January 11, 1950, as given in table 2, being 10 days later in January than the original Roman cycle date I, which fell on January 1, 1924.

B. TEMPERATURE AT WASHINGTON

In previous papers I have drawn attention to a regular periodic variation of 6.6485 days' length in the output of radiation from the sun.³ Though quite regular intervals occur in the solar variation, terrestrial responses thereto are sometimes 1, 2, or rarely 3 days from their expected dates. This is due to the complexity of the atmospheric constituents and reactions. All terrestrial responses to solar impulses are subject to lag. For instance, the warmest part of the day occurs from 1 to 6 hours after noon at various stations of the earth. The lag is not constant from day to day at any station. Hence, from analogy, the irregularity of terrestrial responses to the 6.6485-day solar variation is not surprising. Nevertheless they are notable in magnitude. As shown in earlier papers they range from 2° to 20° F. in the temperature of Washington. This statement will be found confirmed in figures 2 and 3.

Notwithstanding the differences in lag just referred to, which cause displacements of the terrestrial responses, it seemed to me worth while, in January 1948, to predict for the ensuing year the 55 dates when minima of temperature with respect to surrounding days might be anticipated in Washington. In doing so I recognized that actual minima would sometimes fall 1, 2, or even rarely 3 days from the dates predicted. In January 1949 the prediction was compared with the event. Figure 1 shows the numbers of days when the observed minima coincided, or fell 1, 2, or 3 days from the predicted dates in 1948.

The published predictions for 1948 and 1949 (above cited) were made with the original value of the length of the period. I now give in table 3 new dates to replace those published for 1949 in a previous

³ Smithsonian Misc. Coll., vol. 107, No. 4, 1947; vol. 111, No. 6, 1949; vol. 111, No. 13, 949. The period was originally determined as 6.6456 days. But in the last of the three papers cited a correction of 0.0029 days was found, thus making the preferred period 6.6485 days.

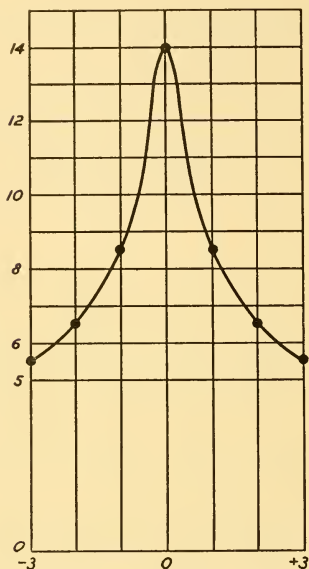


FIG. 1.—Frequency of minima, -3 to $+3$ days from dates predicted in 1948.

TABLE 3.—Corrected dates in 1949 and 1950 when minima were due in Washington temperatures

	1949					1950				
	Jan.	5	11	18	25	31	5	12	19	25
Feb.	7	14	20	27		1	8	14	21	28
Mar.	6	12	19	25		6	13	20	26	
Apr.	1	8	14	21	28	2	8	15	22	28
May	4	11	18	24	31	5	12	18	25	
June	7	13	20	27		1	7	14	21	27
July	3	10	17	23	30	4	11	17	24	30
Aug.	5	12	19	25		6	13	19	26	
Sept.	1	8	14	21	28	2	8	15	22	28
Oct.	4	11	18	24	31	5	12	18	25	
Nov.	7	14	20	26		1	7	14	21	27
Dec.	3	10	16	23	30	4	10	17	24	30

paper. They are based on the corrected period, 6.6485 days, and assuming January 17.0000, 1946, as the basic date of temperature minimum at Washington.

In checking the results for 1949 I prepared a table of 7 columns and 55 lines. The departures from normal temperatures for dates

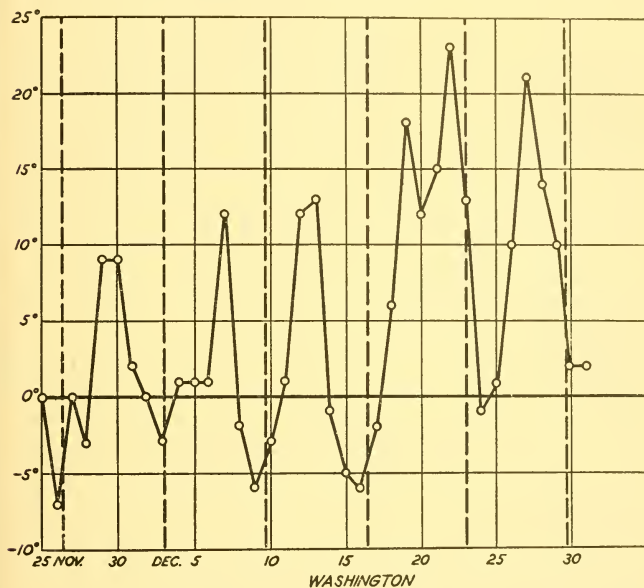


FIG. 2.—Temperature departures from normal at Washington, December 1949. Dotted lines indicate predicted dates for minima.

predicted to yield minima of Washington temperatures according to table 3, I entered in the fourth column. In each of the 55 lines I then entered the departures for the 3 preceding and 3 following days, along with the central predicted date. This made up a table of 7 columns and 55 lines. In this way 20 days were used twice, owing to overlapping. To obviate this defect, I cut off the temperature departures on overlapping dates, alternately from the first and the seventh columns, removing 10 departures from each of these columns. From this table, which to save printing I do not publish, I found the column in each line which carried the minimum temperature for that

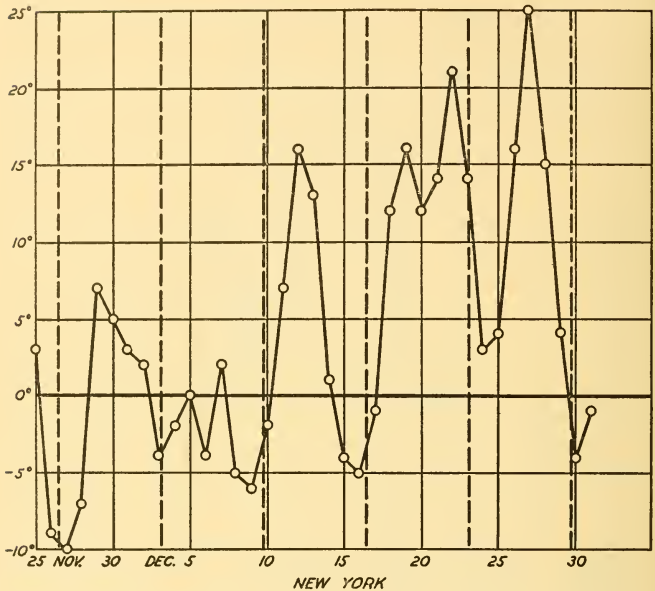


FIG. 3.—Temperature departures from normal at New York, December 1949. Dotted lines indicate predicted dates for minima.

line, and then took the sums for each column. The results are shown in table 4.

TABLE 4.—Frequency of minima of Washington temperatures with respect to the dates of predicted minima of 1949

Days from predicted dates.....	-3	-2	-1	0	+1	+2	+3
Numbers of days of minima.....	5	11	4	11	9	9	6

I also took the mean values of the departures of temperature from normal for the 7 columns of the table of 55 lines. These results are given in table 5.

TABLE 5.—Average temperature departures at Washington with respect to the dates of predicted minima of 1949

Days from predicted dates.....	-3	-2	-1	0	+1	+2	+3
Average temperature departures...	4.46	5.16	4.87	5.42	3.96	3.60	3.87

It is clear that the prediction for 1949 was less successful than that for 1948, illustrated in figure 1. In other words, the displacements

of temperature minima from dates expected to suit the solar period of 6.6485 days were more considerable in 1949 than in 1948. These displacements, as explained above, are attributed to the complexities of atmospheric reactions. I postpone further remarks to the "Discussion" below.

C. NEW YORK TEMPERATURES

As shown in a previous paper,⁴ a comparative study of Washington and New York temperatures over the interval of 21 years, 1928 to 1948, with reference to the solar period of 6.6485 days, indicated that this solar variation strongly affected the temperatures in both cities, and almost identically. By the kindness of E. J. Christie, Meteorologist in Charge at New York, I have received Form 1030 for the year 1949, which gives the daily departures from normal temperatures there. I have treated these data exactly as I have described above for Washington. The results are given in tables 6 and 7.

TABLE 6.—*Frequency of minima of New York temperatures with respect to the dates of predicted minima of 1949*

Days from predicted dates.....	-3	-2	-1	0	+1	+2	+3
Numbers of days of minima.....	9	4	6	11	13	4	8

TABLE 7.—*Average temperature departures at New York with respect to the dates of predicted minima of 1949*

Days from predicted dates.....	-3	-2	-1	0	+1	+2	+3
Average temperature departures...	4°35	4°49	4°75	4°73	3°53	3°76	4°00

D. DISCUSSION OF TEMPERATURES

Neither at Washington nor at New York does the year 1949 show, as a whole, a clear indication of the importance of the solar variation of 6.6485. Were it not for the extensive evidence given in Smithsonian Miscellaneous Collections, vol. 111, No. 13, one would conclude from the year 1949, alone, that this supposed periodic temperature effect is illusory. Certainly one would be inclined to conclude that the period offers little promise of being a useful means for predicting temperatures a year in advance, as was attempted with some success in 1948.

But individual months, even of 1949, give a different impression. In figures 2 and 3 I give for Washington and New York the actual marches of departures from normal Fahrenheit temperatures, from November 25 to December 31, 1949. In both figures the dotted lines

⁴ Smithsonian Misc. Coll., vol. 111, No. 13, 1949.

are drawn exactly on the dates when minima of temperatures should arrive, counting intervals of 6.6485 days from January 17.0000, 1946. The December minima in these figures 2 and 3 all fall within 1 day or less of the expected dates. As shown in Smithsonian Miscellaneous Collections, vol. III, No. 13, so in figures 2 and 3, the two cities behave almost identically. The average range of the periodic fluctuation is $18^{\circ}6$ F. at Washington, and $18^{\circ}0$ F. at New York. This is about at the maximum for the year. In July, as stated in Smithsonian Miscellaneous Collections, vol. III, No. 13, the range is much less. But surely one may conclude that, though not as yet thoroughly available for long-range temperature prediction, the period of 6.6485 days is a major factor in weather.





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AND METHODS

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TREE GROWTH AND RAINFALL—A STUDY OF CORRELATION AND METHODS¹

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The purpose of the present study is to test critically the covariation of tree growth and rainfall—tree growth as measured by the thicknesses of growth layers on increment cores. Three desiderata were the bases of the study. First, an altitudinal zone was to be selected above the region of violent fluctuations of soil moisture but below the region of excessive accumulation and possible carry-over from season to season. This would avoid the forest-border zone where temporary depletion of soil moisture during the growing season could bring growth to a halt temporarily and possibly cause multiplicity of growth layers during that season.

Second, the number of trees sampled was to be held to a minimum in order to avoid excessive duplication of record and to avoid inclusion of trees from habitats so diverse that the merged record would become blurred. The number, however, was to be sufficiently large to absorb any differences in relative growth-layer thicknesses from tree to tree due to slight variations in site factors local to the individual trees.

Third, the trees were to be selected *in the field* on the basis of ecologic principles, after which each core, unless marred by accident or disease, would enter into the group record whether or not the relative thicknesses of its growth layers closely agreed with those of the other cores.

The writer is aware² of the shortcomings and the possible misrepresentation inherent in the use of rain-gauge records taken some

¹ Grateful acknowledgment is made to Dr. A. Wetmore and to the Smithsonian Institution, which supported the entire project. To Dr. R. Sidwell gratitude is due for courtesies extended in the field. Herbert Gross, of Macalester College, was of much assistance not only in the preparation of the figures but also in the lively interest he evinced in the problem. Rainfall data from 1931 to 1946 were obligingly supplied by the Weather Bureau office in Albuquerque, N. Mex.

² Bot. Rev., vol. 7, pp. 649-713, 1941; Journ. Forestry, vol. 40, pp. 614-620, 1942.

miles from the site of the trees, in the use of a single radius to represent the entire volume growth of a tree, and in the emphasis on a single growth factor. However, if significant results can be obtained, in spite of handicaps, by proper selection of trees from the correct habitat, a critical test is highly worth while in view of the simplicity and directness of method. Heretofore, many of the correlations³ between tree growth and rainfall have been discouraging unless the data were smoothed to an extent that direct responses were masked and only general trends revealed.

LOCATION AND TREE DESCRIPTION

The increment cores came from trees that grew near and on Holman Pass, in the Sangre de Cristo Range of north-central New Mexico, about 41 miles by road or about 35.5 miles airline north-northwest from Las Vegas (fig. 1). In so far as the life zones were concerned, the collection extended upward from mid-Transition into the lower portion of the Canadian.

All the trees sampled were dominant or codominant and in the timber stage of development.⁴ On the whole, the ponderosa pines were slightly more mature than the other species. Neighboring trees not sampled were sufficiently distant to avoid undue competitive influence as far as site factors were concerned. Furthermore, the locations were chosen so that abnormal drainage toward or away from the trees was at a minimum. The soils were in no sense tight or lacking in aeration.

In all, nine trees were sampled and designated by the initials HPC, for Holman Pass Collection. The trees from which samples HPC 1 to 4 were taken grew on a nearly flat area a mile southeast of the Pass at an elevation of 9,000 feet. All four were within 150 yards of one another. The black soil contained numerous pebbles and boulders. Cores HPC 5 and 6 came from trees that grew on the Pass itself at an elevation of 9,450 feet. In spite of the fact that the site was on top of the actual pass, the trees stood in the middle of a broad, essentially flat area. The soil was derived from shale and sandstone bedrock, fragments of which remained. Between 7 and 8 miles west of the Pass and down Rio Pueblo Canyon the location of

³ Many of these are listed and discussed in *Bot. Rev.*, vol. 7, pp. 687-698, 705-713, 1941.

⁴ Following the classification of James W. Toumey and Clarence F. Korstian, *Foundations of silviculture upon an ecological basis*, p. 268, 1937. New York.

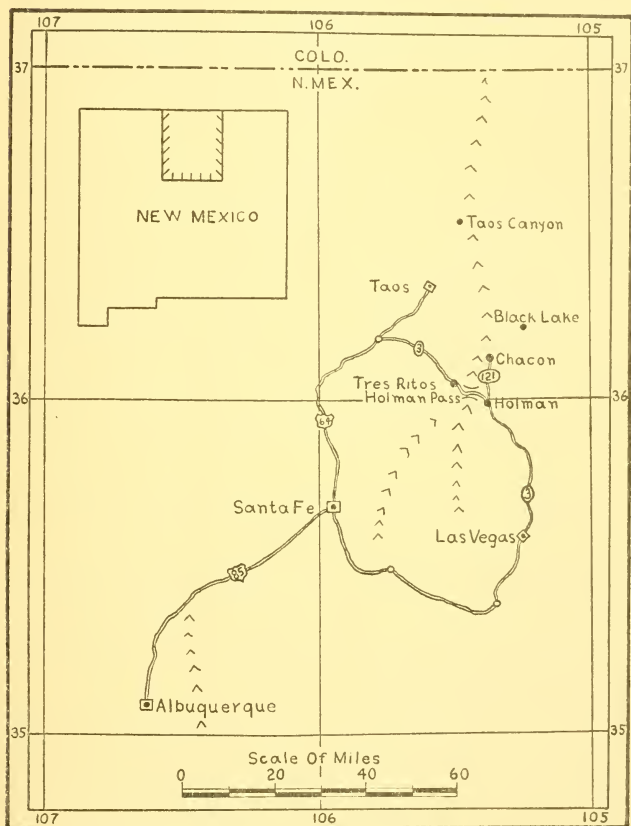


FIG. 1.—General location map for Holman Pass collection and rainfall stations.

the trees for HPC 7 to 9 was chosen at an elevation of approximately 8,000 feet. Here ponderosa pines were more mature and more dominant than at the other two sites. The trees grew on top of a very gently sloping terrace whose edge stood 20 feet above the stream channel. Toward the south the terrace top rose gently to a steeper, heavily wooded slope over 400 feet away. The soil, granitic in composition, contained numerous pebbles and boulders.

Individual tree and core descriptions are given below in concise form:

HPC 1. Ponderosa pine (*Pinus ponderosa*). 14 inches DBH. Average thickness of growth layers 1.61 mm. Range 1850-1946. Growth-layer sequence variable. Average departure from mean 0.58 mm., or 36 percent.

HPC 2. Ponderosa pine. 12 inches DBH. Distant 100 yards from HPC 1. Average thickness of growth layers 1.86 mm. Range 1850-1946. Growth-layer sequence variable. Average departure from the mean 0.54 mm., or 29 percent.

HPC 3. Foxtail pine (*P. aristata*). 24 inches DBH. Midway between HPC 1 and 2. Average width of growth layers 1.32 mm. Range 1770-1946. Growth-layer sequence variable. Average departure from mean 0.51 mm., or 39 percent.

HPC 4. White fir (*Abies concolor*). 15 inches DBH. Wettest location for group east of Pass; slight drainage toward tree. Average thickness of growth layers 2.93 mm., corrected to average 1.46 mm. Range 1880-1946. Growth-layer sequence only fairly variable. Average departure from mean 0.57 mm., or 39 percent.

HPC 5. Douglas fir (*Pseudotsuga taxifolia*). 15 inches DBH. Average width of growth layers 1.16 mm. Range 1810-1946. Growth-layer sequence variable. Average departure from mean 0.45 mm., or 39 percent.

HPC 6. Foxtail pine. 14 inches DBH. Distant 20 yards from HPC 5. Average width of growth layers 1.38 mm. Range 1820-1946. Growth-layer sequence uniform. Average departure from mean 0.36 mm., or 26 percent.

HPC 7. Ponderosa pine. 23 inches DBH. Distant 70 feet from edge of terrace above stream. Average thickness of growth layers 1.91 mm. Range 1830-1946. Growth-layer sequence uniform and rhythmic. Average departure from mean 0.52 mm., or 27 percent.

HPC 8. Ponderosa pine. 13 inches DBH. Distant 20 feet from edge of terrace above stream. Least mature. Ground-water relations make site better drained than that of HPC 7. Average thickness of growth layers 3.74 mm.; corrected to average 1.46 mm. Range 1897-1946. Growth-layer sequence only fairly variable. Average departure from mean 0.53 mm., or 36 percent.

HPC 9. Ponderosa pine. 19 inches DBH. Midway between terrace edge and base of steep slope. Wettest location for trees west of Pass. Average thickness of growth layers 2.71 mm.; corrected to average 1.46 mm. Range 1857-1946. Growth-layer sequence variable. Average departure from mean 0.44 mm., or 30 percent.

The designations variable, fairly variable, or uniform were assigned directly from the wood by visual judgment alone.

METHODS

Because all cores consisted of sound wood, none was discarded. Furthermore, because site factors such as light, drainage, slope, ground-water relations, and competition were evaluated on the spot as closely as possible, no reason existed immediately after the collection had been made for the rejection of any specimen. The collection was considered a normal representation of the site factors at the three chosen localities even though the sequences differed to a great extent in variability and average growth-layer thicknesses. At the time the cores were taken there seemed to be no reason why different species should show differences except those due to slight variations of site factors peculiar to each tree. Such a factor as soil aeration had to be judged by soil texture and composition and visible soil-water relations. There was no opportunity for analyses or measurements. Indeed, this problem of selection in the field, without measurements, was of great importance: could local site factors be judged with sufficient accuracy to demand the inclusion of each core as a representative specimen in the general collection? If so, choice in the field, based on ecologic principles, would be a dependable method of selection whose integrity could be questioned only on field evidence or its derivatives.

Treatment of the wood.—The cores and the growth layers they contained were subjected to the following procedure to prepare them for correlation among themselves and with rainfall.

1. The cores were glued in a groove sunk into the curved side of half-inch half-round and "shaved" by razor sufficiently to expose the growth layers clearly.⁵

2. Beginning with the increment for 1946, which was complete because of the time of sampling, October 5, 1946, the growth layers were counted inward and dated on the assumption that each sharply bounded layer represented a year.

3. Skeleton⁶ plots were set up on coordinate paper, each ordinate representing a year. If a sharply bounded growth layer was decidedly thinner than its immediate neighbors an ink line was drawn on the ordinate appropriate to its date, the height of the line being inversely proportional to the thickness of the growth layer. The resultant skeleton plots and the master plot derived from them are shown on

⁵ Principles and methods of tree-ring analysis. Carnegie Institution of Washington Publ. No. 486, p. 6, 1937.

⁶ *Ibid.*, pp. 14-16.

figure 2. Thus, the wood specimens were cross-dated with one another; that is, growth layers taken to be equivalent in time were set in line with one another.

4. The thicknesses of the growth layers were measured to hundredths of a millimeter by means of a measuring microscope. These measurements are called raw data in millimeters.

5. The average thicknesses of the growth layers on the sequences HPC 4, 8, and 9 were corrected downward to approximate the averages of the other sequences. Otherwise, if a sequence of high average thickness were one of several merged into a group, its high average would unduly influence the values in the group.

6. The raw data in millimeters of each sequence were changed into percentages of the sequence mean in order to establish an identity of units and an identity of base line between tree growth and rainfall.

7. The raw percentages were smoothed by the formula

$$\frac{a+2b+c}{4}.$$

8. Various sequences were merged into groups and smoothed.

Groups.—The nine sequences divided themselves geographically into three groups—east of the Pass, on the Pass, and west of the Pass. Nevertheless, other groupings were arranged in order to make the tests not only as critical but also as thorough as possible so far as comparison with rainfall was concerned.

The following groups were set up:

Group 1 (G 1). Trees 1-5, 8, and 9. Variable and fairly variable sequences only.

Group 2 (G 2). Trees 1-3, 5, and 9. Variable sequences only.

Group 3 (G 3). Trees 1-3, and 9. Most variable sequences based upon a visual study of the wood samples. Douglas fir omitted.

Group 4 (G 4). Trees 1-4. East of the Pass.

Group 5 (G 5). Trees 5 and 6. On the Pass.

Group 6 (G 6). Trees 8 and 9. West of the Pass, exclusive of the tree whose sequence is uniform.

Group 7 (G 7). Trees 1-9. All trees.

Group 8 (G 8). Trees 1, 2, and 9. Ponderosa pines with variable sequences.

Group 9 (G 9). Trees 7-9. West of Pass.

Group 10 (G 10). Trees 1-3, and 7. From the drier sites.

Group 11 (G 11). Trees 4-6, and 9. From the wetter sites.

The primary groups are numbers 4, 5, 9, 10, 11, and 7.

Selection of rainfall stations and the treatment of data.—A mountainous country permits little choice in the selection of rainfall stations. Fortunately, one station, Chacon, lies approximately 7 miles, airline

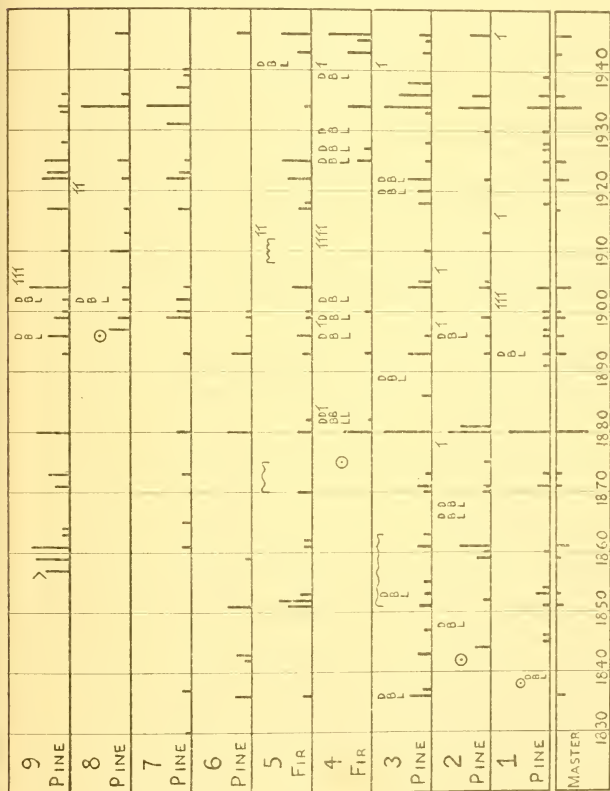


FIG. 2.—Skeleton plots of the nine trees, HPC 1 to 9, and their synthesis into a master plot. The longer the inked line is, the narrower the growth layer. "DBL" means double and "T" means thick. A wavy line includes a group of narrow growth layers. A dot inside of a circle rests on the central growth layer of the tree.

distance, north-northeast of Holman Pass. Unfortunately, its record is short compared with that of Santa Fe, distant 40 miles to the southwest from the Pass. Figure 1 shows the general relations.

Pertinent data in regard to the stations follow:

Chacon: 7 miles north-northeast, east of divide, in the mountains. Elevation 8,510 feet. Length of continuous record 1909-1941.

Black Lake: 19 miles north-northeast, east of the divide, in the mountains. Elevation 8,348 feet. Length of continuous record 1909-1946.

Taos: 24 miles north-northwest, west of mountains. Elevation 6,983 feet. Length of continuous record 1901-1945.

Taos Canyon: 32 miles north, west of divide, in the mountains. Elevation 8,959 feet. Length of continuous record 1909-1941.

Las Vegas: 35.5 miles southeast by south, east of mountains. Elevation 6,400 feet. Length of continuous record 1887-1943.

Santa Fe: 40 miles southwest, west of mountains. Elevation 7,013 feet. Length of continuous record 1850-1944.

Albuquerque: 101 miles southwest, west of Sandia Mountains. Elevation 5,196 feet. Length of continuous record 1892-1946; partial record 1850-1861, 1863-1867, 1878-1879, and 1889-1890.

Month-intervals chosen for the correlative tests between rainfall and tree growth were:

November-May	May-July
January-May	May-August
January-August	April
March-April	May
March-June	June
March-July	July
May-June	August

Rainfall data were then subjected to the treatment here outlined:

1. Addition of monthly rainfall totals in order to obtain the rainfall of the intervals listed above. These sums gave raw data in inches.
2. The raw data of each interval in inches were changed into percentages of its own mean in order to establish an identity of units and an identity of base line between rainfall and tree growth.
3. The raw percentages were smoothed by the formula

$$\frac{a+2b+c}{4}$$

4. The raw percentages for the stations Chacon, Black Lake, Las Vegas, and Taos Canyon were merged into a group record for the intervals January-August and March-July. These stations were chosen because their interval averages were nearly the same.

Method of correlation.—Because the purpose of the study was the correlation of rainfall variation with growth variations and because

the basic data constitute a continuous time series, the trend method⁷ of correlation has been used. This method, in the coefficient t , gives a measure of parallel variation combined with amount of that variation. If t equals 1.00, the trends in both sets of data, tree growth and rainfall, are wholly parallel or in the same direction; if t equals -1.00, the trends are wholly opposite. Tests were constantly made to detect the undue influence of one or two entries should such be present. The ratios of opposite to parallel trends are included in the tables with the trend coefficients. With the trend method of correlation, secular trends or long-period fluctuations did not have to be eliminated. These are ignored for the present especially because the history of the stand and the histories of the individual trees are unknown except as revealed on the wood itself.

The quality of the correlations between tree growth and rainfall on identical years was tested by application of a one-year lag and by reversal of data. In all cases, the correlations dropped to a value of no significance.

Although the purpose of the work was the comparison of year-to-year variations, correlations involving smoothed data (second intermediate) were nevertheless carried through the main part of the calculations. The majority of the coefficients did not increase significantly over those using raw data; in fact, many decreased.

The initial questions, then, to be answered by use of the trend method, were: If rainfall increases or decreases, does tree growth, as shown by such simply obtained samples as increment cores, increase or decrease in like direction? To which rainfall interval does the tree growth correspond? As the work progressed new problems came to light and soon carried the study far beyond the original objectives.

STUDY OF THE GROWTH LAYERS

Cross-dating.—This process consists of establishing the identity in time of growth layers on different sequences by matching narrow growth layers, in particular, from one specimen to another. Judgment as to narrowness depends upon visual comparison with immediately adjacent growth layers and should not be confused with or substituted for mathematical expressions. Obviously, cross-dating can possess various degrees of excellence. What constitutes reliable cross-dating is a moot point and may, perhaps, be largely dependent

⁷ A rapid method of correlation for continuous time series. Amer. Journ. Sci., vol. 240, pp. 437-442, 1942.

upon the individual investigator. Here, it is important to know if cross-dating is a prerequisite to the merging of sequences for correlation purposes.

Figure 2 shows the so-called skeleton plots for HPC 1 to 9 and a master plot made by a synthesis of the nine. The heights of the inked lines bear an inverse ratio to the widths of the growth layers on the wood as judged by the eye. No actual measurements enter the skeleton plots. In order to judge the quality of the relationships, the above figure should be compared with figure 3, which shows excellent cross-dating from a forest-border area. The conclusion is obvious: cross-dating as exhibited by the Holman Pass specimens is of remarkably poor quality. One is tempted to say it does not exist at all, for, if the dates were entirely unknown and within a range of several centuries, one would have difficulty in convincing others that the sequences match growth layer for growth layer as they stand. In the present case the validity of the cross-dating, or the only assurance that the growth layers grew on the dates assigned to them on the skeleton plots, rests on two circumstances: (1) the narrowness of the growth layers designated 1880 and 1893 and (2) the probability that the soil moisture in the zone where the trees grew was sufficiently adequate to prevent a temporary halt in growth during any one growing season.

A detailed comparison of the growth layers on all specimens for each date in succession (fig. 2) brings out a lack of correspondence that appears to emphasize a certain degree of individuality in the site factors at each tree.

An analysis of figure 2 was made, and the results were arranged in table 1. The record covers 116 years. Out of this length of record only two cases exist, the growth layers designated 1880 and 1893, wherein the growth layers are notably narrow on the eight specimens bearing them. Two cases, 1836 and 1934, could perhaps be classed with the previous two because the one growth layer that does not conform on each exists on a so-called uniform sequence, one on HPC 7 and the other on HPC 6. Entries in table 1 wherein no narrow growth layer exists on any one of the specimens number 55 cases. With the number of specimens in the count disregarded, there are 22 cases where one growth layer is atypical, 23 cases where two growth layers are atypical, 12 where three are atypical, and 2 where four are atypical. For more than half the years the sequences are from 11 to 50 percent out of agreement with one another.

TABLE 1.—Incidence of growth-layer type
Analysis of figure 2

1831				1871				1911			
Narrow	Av.	Thick	Dbl.	Narrow	Av.	Thick	Dbl.	Narrow	Av.	Thick	Dbl.
1831....0	4			1871....4	3			1911....0	8	1	
0	4			0	7			0	8	1	
0	4			4	3			2	5	2	
0	4			0	7			0	7	2	
0	4			1	7			0	9		
3	1	I		0	8			0	8	1	
2	2			0	8			4	5		
0	5			0	7	I		3	6		
0	5	I		0	8			0	9		
0	5			8	0			1	7	I	I
1841				1881				1921			
1841....0	5			1881....1	7			1921....0	8	1	
1	4			2	6		I	7	2		I
2	4			0	8		I	2	7		
1	5			0	7	I		0	9		
1	5			0	8			7	2		I
1	5			1	7			0	9		
1	5			0	8			2	7		I
0	6	I		0	8			3	6		
0	6			0	8		I	0	9		
0	6			0	8			2	7		I
1851				1891				1931			
1851....4	2			1891....1	7			1931....1	8		
2	4			0	8			0	9		
3	3	I		8	0		I	2	7		
1	5			0	8			8	1		
1	5			0	8			0	9		
0	6			5	3		3	5	4		
1	6			2	7			1	8		
0	7			0	7	2		1	8		
3	4			7	2		I	2	7		I
2	5			6	3			2	7		
1861				1901				1941			
1861....5	2			1901....0	8	I		1941....0	7	2	I
1	6			3	5	I	3	0	9		
2	5			0	8	I		3	6		
1	6			7	2			0	9		
1	6			2	6	I		2	7		
0	7	I		0	8	I		6	2	I	
0	7			0	7	2					
0	7	I		1	8						
0	7			0	9						
3	4			3	6						

NOTES:

1836—an average growth layer on HPC 7, a uniform sequence.

1934—an average growth layer on HPC 6, a uniform sequence.

Correlation.—Because of the poor quality of the cross-dating and because of the desire to compare the sequences each with the other based upon precise measurements, the sequences were subjected to statistical correlation. Table 2 gives the trend coefficients and the ratios of opposed to parallel trends for certain trees and certain groups. The bases of selection are evident from the captions in the table.

A comparison of the averages for uniform and variable sequences shows that the uniform have a considerably higher trend coefficient,

TABLE 2.—*Holman Pass collection**Trend coefficients and ratios of opposed trends*

1850 to 1897		1898 to 1941		1850 to 1897		1898 to 1941	
<i>Uniform sequences</i>				<i>Trees east of Pass</i>			
4 vs. 6		0.82	(0.36)	1 vs. 2	0.62 (0.40)	0.90	(0.23)
4 vs. 7		0.83	(0.41)	1 vs. 3	0.86 (0.34)	0.94	(0.20)
6 vs. 7	0.66 (0.38)	0.57	(0.36)	1 vs. 4		0.79	(0.32)
4 vs. 8		0.88	(0.27)	2 vs. 3	0.85 (0.30)	0.97	(0.11)
				2 vs. 4		0.83	(0.23)
				3 vs. 4		0.96	(0.25)
<i>Variable sequences</i>				<i>Trees on Pass</i>			
1 vs. 5	0.36 (0.53)	0.73	(0.20)				
1 vs. 9	0.32 (0.42)	0.81	(0.23)				
5 vs. 9	0.26 (0.42)	0.71	(0.25)	5 vs. 6	0.79 (0.34)	0.91	(0.20)
<i>Intergroup</i>				<i>Trees west of Pass</i>			
4 vs. 5	0.90 (0.32)	0.88	(0.20)	7 vs. 8		0.87	(0.23)
4 vs. 9	0.72 (0.36)	0.87	(0.23)	7 vs. 9	0.72 (0.40)	0.63	(0.30)
5 vs. 9	0.52 (0.49)	0.76	(0.27)	8 vs. 9		0.70	(0.30)
10 vs. 11	0.94 (0.21)	0.97	(0.14)				

whereas the variable have a very slightly lower trend ratio. If anything, the uniform have a slight advantage.

Intragroup comparisons east of the Pass, on the Pass, and west of the Pass indicate on the whole that correlations are distinctly higher between trees within their own groups than between trees in different groups. If the groups are averaged, this higher correlation is shown even more clearly. Hence, trees grouped together appear to correlate more closely than those rather widely separated.

The matter of distance merits further attention. If the trend ratios of the trees in table 2 are arranged in order of distance within the

group, table 3 results. Among the species, PP means ponderosa pine, FP foxtail pine, WF white fir, and DF Douglas fir. The interval of years in either case ends on 1941. Table 3 is divided into three groups: the first comprising trees east of the Pass, the second on the Pass, and the third west of the Pass.

In general, agreement declines with increasing distance, a distance measured in feet. Site factors at the surface appear to the eye to be nearly identical among the trees of any one group, but apparently the factors do change within short distances in spite of appearances. Proximity outweighs difference of species as well as presence or absence of variability. Factors present at the immediate location of the individual tree, or what may be called microsite factors, appear

TABLE 3.—*Holman Pass collection**Ratios of opposed trends*

Distance apart	Trees	Species	1898-1941	Total sequence
150 feet	2 vs. 3	PP vs. FP		
	1 vs. 3	PP vs. FP	0.18	0.24
	2 vs. 4	PP vs. WF		
300	1 vs. 2	PP vs. PP	0.24	0.29
	3 vs. 4	FP vs. WF		
450	1 vs. 4	PP vs. WF	0.32	0.34
60 (ca.)	5 vs. 6	DF vs. FP	0.20	0.27
50	7 vs. 8	PP vs. PP	0.23	
230	7 vs. 9	PP vs. PP	0.30	
	8 vs. 9	PP vs. PP		

to exert a strong measure of control on tree growth. That trees separated by a distance of a mile or more do show a parallel agreement of variation in a majority of years indicates the influence of a gross factor uniformly variable within limits over the area. However, when it is remembered that the trend between two growth layers on one tree compared with the trend between two growth layers of the same date on another tree, no matter how remote, can vary only in two directions, parallel or opposite, some allowance must be made for accidental similarities. The same principle, of course, holds true where visual comparisons are made in so-called cross-dating because in the consideration of two growth layers of same date in different trees one growth layer can only be thinner than, thicker than, or of the same thickness as, the other growth layer.

Correlations between groups (table 2) east of Pass, on Pass, and west of Pass are only fair. They show a mixed influence of site and distance. Groups 4 and 5 are relatively close together but have dissimilar sites—they have the highest correlation; groups 4 and 9 are far apart but have somewhat similar sites—they have correlation of intermediate value; and groups 5 and 9 are far apart and have very dissimilar sites—they have the lowest correlation.

Table 2 suggests something much more surprising than the dominant influence of local site factors. The correlation among different trees and among different groups as shown not only by the trend coefficients but also by the trend ratios are distinctly less for the period 1850-1897 than for the period 1898-1941. In fact, a few of the trends, and trend ratios, are of such poor quality as to indicate little relationship. Growth factors from 1850-1897 apparently must have had a localized variability which to a certain extent became less localized after 1897.

For further comparisons among the trees the trends were plotted for each tree against every other tree for the total years of record. A comparison of ponderosa pine with other ponderosa pines, of ponderosa with other species, and of other species among themselves shows that species has no bearing upon the trend agreements. A comparison of sequence types, such as variable with variable, variable with uniform, and the like, shows that the type of sequence being correlated is not an important factor. In general terms, however, the closer two trees are together the greater the number of parallel trends. During the period of 44 years from 1898 to 1941, where all nine trees are in the record, there are 15 years with parallel trends. Agreements are concentrated in the 10-year period, 1920-1929, which has 6 parallel trends. Back of 1898, the period of 48 years adds only 9 parallel trends to the 15 of the later period in spite of the fact that the record of the earlier period contains from one to three fewer trees. The striking lack of agreement prior to 1898 appears to fit in with the lack of correlation mentioned in the paragraph above. Again it seems that the microsite factors may have contrasted more acutely from tree to tree or that an over-all factor exerting a general influence on tree growth may have been more areally variable than later.

Growth-layer characteristics.—Table 4 shows the average of year-to-year variations of growth-layer thicknesses on single tree sequences and on three groups. These figures are the measured equivalents of the visual values embodied in the terms variable, fairly variable, and uniform. In the main, the numerical results militate against judgment by eye. Tree HPC 5, for instance, was judged variable and HPC 6 uniform; yet both have nearly the same average variation. However, greater consistency is shown by groupings: for the period, 1898-1941, the average of the variable sequences is 0.36, of the fairly variable 0.32, and of the uniform 0.28.

Table 4 emphasizes the importance of location, not species, as the apparent determinant of average variation. For instance, trees HPC 3 and 6 are both foxtail pines and yet have variations of 0.37 and

TABLE 4.—*Holman Pass collection*

		<i>Average year-to-year variation</i>					
		— to 1897	1898 to 1941	Entire	1850 to 1897	1898 to 1941	
HPC 1.....	1850-	0.22	0.40	0.30	G 10.....	0.26	0.40
2.....	1850-	0.35	0.41	0.38	11.....	0.38	0.27
3.....	1850-	0.31	0.43	0.37	7.....	0.21	0.27
4.....	1880-	0.36	0.28	0.30			
5.....	1850-	0.29	0.19	0.25			
6.....	1850-	0.27	0.21	0.24			
7.....	1850-	0.18	0.35	0.26			
9.....	1857-	0.40	0.39	0.40			

0.24, respectively (0.43 and 0.21 for 1898-1941), the higher value existing in the drier location. It is true that the ponderosa pines have higher variations in general than the other species but HPC 3, a foxtail pine, grew between HPC 1 and 2 and has even a slightly higher average variation.

All trees from the wetter locations (group 11) had higher average variations for the period 1850-1897 than they did for the period 1898-1941. In contrast, the trees in the drier locations (group 10) had lower average variations in the earlier period.

Tables 5 and 6 giving average growth-layer thicknesses and average departures were prepared even though definitive results were not expected because secular trend and long-period fluctuations had not been eliminated. In table 5, group 10 shows an increase and group 11 a decrease of average growth-layer thicknesses from the period 1850-

1897 to that of 1898-1941. The individual trees of group 10 are not consistent among themselves in that HPC 1 and 3 increase decidedly, HPC 2 increases very slightly, and HPC 7 decreases. All trees in group 11 are consistent except for HPC 6 which decreases very slightly. Thus, four trees decrease, two remain practically unchanged, and two increase their average thicknesses for the period 1897-1941 contrasted with that of 1850-1897. Group 7 reflects these influences.

TABLE 5.—*Holman Pass collection**Average growth-layer thicknesses*

		— to 1897	1898 to 1941		1850 to 1897	1898 to 1941
HPC 1.....	1850-	1.28	1.82	G 10.....	1.53	1.70
2.....	1850-	1.87	1.88	11.....	2.26	1.96
3.....	1850-	1.01	1.23	7.....	1.90	1.83
4.....	1880-	3.50	2.95			
5.....	1850-	1.18	0.79			
6.....	1850-	1.52	1.51			
7.....	1850-	1.96	1.86			
9.....	1861-	2.85	2.61			

TABLE 6.—*Holman Pass collection**Average departures*

		— to 1897	1898 to 1941		1850 to 1897	1898 to 1941
HPC 1.....	1850-	0.31	0.36	G 10.....	0.32	0.36
2.....	1850-	0.32	0.27	11.....	0.34	0.30
3.....	1850-	0.45	0.42	7.....	0.18	0.20
4.....	1880-	0.37	0.36			
5.....	1850-	0.39	0.34			
6.....	1850-	0.27	0.21			
7.....	1850-	0.19	0.38			
9.....	1861-	0.31	0.28			

In Table 6, group 10 shows an increase and group 11 a decrease of average departures from the period 1850-1897 to that of 1898-1941. All trees of group 11 are consistent among themselves in the decrease from the earlier to the later period. This is not true for the trees of group 10. Two of them, HPC 2 and 3, actually showed a decrease of average departures and thus conformed with the wet-site trees of group 11. In other words, trees HPC 1 and 7 do not conform with the remaining six trees, yet their influence is sufficiently great to determine the relative values as shown for groups 7 and 10 in table 6.

The data in table 7 were calculated in an attempt to obtain a measure of excess variation over normal. From the earliest to the latest periods shown, HPC 1, 2, 3, and 4 show a rise and decline; HPC 5, 6, and 9 show a general decline; and HPC 7 shows a general rise of values. Six of the trees, but not including HPC 1, have lower values for 1910-1941 than for 1850-1897. As in the case of average departures, it is HPC 1 and 7 which do not conform. In spite of their influence, group 7 shows a slight but progressive decline from the earliest to the latest period. If HPC 1 and 7 are eliminated from group 7, giving group 7 (restricted), the decline becomes more decided.

TABLE 7.—*Holman Pass collection*
Average departure from mean variation

	1850-1897	1898-1941	1910-1941
HPC 1.....	0.17	0.28	0.24
2.....	0.21	0.24	0.20
3.....	0.25	0.26	0.23
4.....	0.23	0.24	0.21
5.....	0.20	0.13	0.11
6.....	0.19	0.16	0.15
7.....	0.15	0.23	0.24
9.....	0.28	0.25	0.20
G 10.....	0.132	0.148	0.136
11.....	0.204	0.118	0.110
7.....	0.110	0.105	0.094
7 (restricted)	0.130	0.105	0.092

Table 8 brings together a short summary of characteristics on the wood in order to emphasize the differences between the two periods 1850-1897 and 1898-1941. Although the differences between groups 10 and 11 appear striking, they actually are due to the influence of two out of eight trees. Elimination of those two trees from group 7 brings it into harmony with group 11. There remain, then, the fundamental differences between the periods 1850-1897 and 1898-1941. Do they reflect a change in amount of rainfall with its attendant changes in rainfall characteristics, or a change in the rainfall interval important to tree growth, or both, or some other change? In a previous paragraph a striking dearth of trend agreements among the trees was pointed out for 1850-1897 in contrast with succeeding years. A reexamination of the data shows that the dearth does not apply quite so drastically to the trees from the wetter locations. This

matter of trend agreement appears to be another facet of the general problem brought out by the changes of characteristics on the wood through the years from 1850 to 1941.

TABLE 8.—*Holman Pass collection*

<i>Characteristics</i>		
	1850-1897	1898-1941
<i>Average variation</i>		
G 10.....	0.26	0.40
11.....	0.38	0.27
7.....	0.21	0.27
<i>Average thickness</i>		
G 10.....	1.53	1.70
11.....	2.26	1.96
7.....	1.90	1.83
<i>Average departure</i>		
G 10.....	0.32	0.36
11.....	0.34	0.30
7.....	0.18	0.20
<i>Average departure from mean variation</i>		
G 10.....	0.132	0.148
11.....	0.204	0.118
7.....	0.110	0.105

STUDY OF RAINFALL CHARACTERISTICS

Two tasks were set out for consideration in connection with the rainfall data: (1) to determine the interrelationships among the stations of usable records in the vicinity of Holman Pass and (2) to determine the characteristics of those records. As to the first task, it is necessary to know the extent of the differences between two adjacent stations in order to appreciate and allow for the possible differences between the trees and the station nearest to them. As to the second task, it is desired to learn whether or not the rainfall shows any differences between the two periods 1850-1897 and 1898-1941, and, if it does, to compare the differences with those obtained from a study of growth-layer sequences.

Interstation correlations.—Table 9 shows the trend coefficients and ratios of opposed trends between Chacon, the nearest station to Holman Pass, and six other stations for eight selected time intervals. These intervals were chosen on the basis of their possible influence on tree growth. On the whole, the correlations show a remarkable consistency. Those comparisons which do not include part or all of the summer rainfall are commonly higher than those which do. Furthermore, the longer the interval under comparison is, the poorer the correlation in general. Black Lake, the nearest to Chacon in distance as well as elevation, does not have the best correlation with Chacon. Las Vegas has the greatest similarity, a station farther away, 2,100 feet lower, and out beyond the foot of the main range of mountains. Santa Fe rainfall correlates with that of Chacon to a degree equal to the correlation between Black Lake and Chacon. Even Albuquerque is little less in degree of similarity. The best correlations are for the March-April intervals with Black Lake and Albuquerque which show ratios of opposite trends with respect to Chacon of 0.12 and 0.09.

It is scarcely necessary here to do more than refer briefly to the many observations of differences in rainfall at gauges spaced rather closely together. For instance, Stout⁸ records a study of July 1948 rainfall on a plot centering at El Paso, Ill. Two stations, 10 miles apart, had 10.44 and 5.93 inches of rainfall. Two other stations, 3 miles apart, showed a difference of 77 percent. Localization of single storms is on occasion even more pronounced. On June 30, 1947, near Lubbock, Tex., 4 to 5 inches of rain fell in a belt about 2 miles wide, whereas none fell 2 miles to the west and 0.26 inches 8 miles to the east. Of course, this may be unusual, but at least it is more or less typical of extreme forest-border conditions.

Furthermore, it must be remembered in comparing tree growth with the rainfall of a station that, as pointed out by Landsberg,⁹ a rain gauge samples but does not measure rainfall and therefore "the areal significance of precipitation amounts caught at a station is very restricted. . . ." These characteristics of rainfall must be duly weighed when the growth of selected trees is compared with the record of a station some miles distant. The trees may respond to the rainfall they themselves receive but differ somewhat from that received by the weather station.

⁸ Weatherwise, vol. 1, pp. 112-113, 1948.

⁹ Landsberg, H., Critique of certain climatological procedures, Bull. Amer. Meteor. Soc., vol. 28, pp. 187-191, 1947.

TABLE 9.—*Correlation between Chacon rainfall and that of other stations*
Trend coefficients and ratios of opposed trends
 1909-1941

	Mar.- July	Jan.- Aug.	Mar.- June	May- Aug.	May- June	Jan.- May	Nov.- May	Mar.- Apr.	Av.
Black Lake	0.61 (0.41)	0.93 (0.22)	0.93 (0.28)	0.93 (0.28)	0.92 (0.16)	0.88 (0.19)	0.92 (0.19)	0.99 (0.12)	0.89 (0.23)
Taos	0.86 (0.16)	0.78 (0.22)	0.89 (0.22)	0.87 (0.22)	0.85 (0.19)	0.80 (0.31)	0.86 (0.23)	0.90 (0.25)	0.85 (0.22)
Taos Canyon	0.92 (0.22)	0.86 (0.28)	0.95 (0.22)	0.86 (0.37)	0.92 (0.16)	0.91 (0.19)	0.94 (0.19)	0.97 (0.16)	0.92 (0.22)
Las Vegas	0.95 (0.25)	0.91 (0.12)	0.97 (0.22)	0.91 (0.28)	0.87 (0.19)	0.95 (0.16)	0.93 (0.13)	0.97 (0.16)	0.93 (0.19)
Santa Fe	0.91 (0.25)	0.72 (0.31)	0.98 (0.12)	0.86 (0.34)	0.95 (0.12)	0.86 (0.22)	0.88 (0.23)	0.90 (0.22)	0.88 (0.22)
Albuquerque	0.89 (0.25)	0.86 (0.31)	0.94 (0.22)	0.66 (0.41)	0.92 (0.25)	0.86 (0.16)	0.78 (0.26)	0.98 (0.09)	0.86 (0.25)
Average	0.86 (0.26)	0.84 (0.24)	0.94 (0.21)	0.85 (0.32)	0.90 (0.18)	0.88 (0.19)	0.88 (0.19)	0.95 (0.16)	

From the qualitative standpoint, the trend ratios of table 9 give a rather clear indication of the amount of agreement to be expected between tree growth and rainfall where the two are as far apart as any two of the rainfall stations. Quantitatively, trend coefficients yield values to be expected in the same fashion. If variations in tree growth mirror variations in rainfall to a high degree then the cor-

TABLE 10.—*Correlation between rainfall intervals at Chacon*
Trend coefficients and ratios of opposed trends
1909-1911

Nov.-May vs.		Jan.-May vs.	
Jan.-Aug.	0.78 (0.26)	Mar.-Apr.	0.92 (0.22)
Nov.-May vs.		Jan.-May vs.	
Jan.-May	0.99 (0.06)	Mar.-June	0.84 (0.22)
Nov.-May vs.		Jan.-May vs.	
Mar.-June	0.82 (0.29)	May-Aug.	0.14 (0.47)
Jan.-Aug. vs.		Jan.-May vs.	
Jan.-May	0.73 (0.28)	May-June	0.18 (0.44)
Nov.-May vs.		Mar.-July vs.	
Mar.-July	0.77 (0.23)	Mar.-Apr.	0.67 (0.31)
Nov.-May vs.		Mar.-July vs.	
May-Aug.	0.21 (0.48)	Mar.-June	0.98 (0.12)
Nov.-May vs.		Mar.-July vs.	
May-June	0.17 (0.45)	May-Aug.	0.85 (0.34)
Nov.-May vs.		Mar.-July vs.	
Mar.-Apr.	0.90 (0.23)	May-June	0.81 (0.22)
Jan.-Aug. vs.		May-Aug. vs.	
Mar.-June	0.87 (0.25)	May-June	0.94 (0.25)
Jan.-May vs.		May-Aug. vs.	
Mar.-July	0.72 (0.22)	Mar.-Apr.	-0.33 (0.66)
Jan.-Aug. vs.		May-Aug. vs.	
Mar.-July	0.97 (0.22)	Mar.-June	0.66 (0.44)
Jan.-Aug. vs.		May-June vs.	
May-Aug.	0.92 (0.25)	Mar.-Apr.	-0.02 (0.47)
Jan.-Aug. vs.		May-June vs.	
May-June	0.69 (0.22)	Mar.-June	0.87 (0.25)
Jan.-Aug. vs.		Mar.-Apr. vs.	
Mar.-Apr.	0.56 (0.38)	Mar.-June	0.90 (0.25)

relation between Holman Pass trees and Chacon rainfall should closely approach or possibly equal the average values set out in table 9. Should this prove to be true, the conclusion is no doubt justified that trees growing in a zone well above critical moisture conditions rather faithfully record rainfall variations at the site from year to year, barring the impact of an "accidental" factor in concentrated form in any one year.

Table 10 sets forth correlations between various month-intervals in

Chacon rainfall. Good correlations in general result under three circumstances: In the lack of summer rainfall in the intervals compared, in the proportion of overlap between the two intervals, and in the length of the intervals. For instance, November-May versus January-May has a trend coefficient of 0.99 and a trend ratio of 0.06 whereas, contrariwise, May-August versus March-April has values of -0.33 and 0.66 . The table as a whole shows great variation and indicates the necessity of comparing tree growth with different rainfall intervals. It goes farther than this. If tree growth is found to correlate with one particular month-interval, then a great quantity of xylem (as a thick growth layer) formed during a certain season suggests copious rainfall for that month-interval; it does not necessarily suggest that the entire year is a wet one.

Rainfall characteristics.—For a study of the influence of a single factor, such as rainfall, on tree growth it is necessary to have long records at the immediate site of the trees. Short records taken a matter of several miles distant can be highly indicative but not necessarily conclusive. In the present case the record at Chacon, 7 miles away, begins with 1909. Therefore, the longer records of Santa Fe and Albuquerque were used, in spite of greater distances, in order to determine possible differences in rainfall characteristics between the periods 1850-1897 and 1898-1941.

Table 11, in the first place, gives the March-July and January-August rainfall for 1909-1941 at the several stations. As will be shown later, the rainfall of March-July is a significant factor in tree growth. In the second place, table 11 gives the rainfall of Santa Fe and Albuquerque for the periods 1850-1897 and 1898-1941 set out for various month-intervals. Two points must be considered. First, there is the striking fact that the average rainfall of March-July for both Santa Fe and Albuquerque was less during the period 1850-1897 than during that of 1898-1941. The same is true for the average rainfall of Albuquerque for January-August. Second, there is the fact that the average rainfall of January-August at Santa Fe was greater during 1850-1897 than for the following 44 years. The reason for this inconsistency with the intervals mentioned in the first point above was suspected as soon as it was determined that the average rainfall of January-May, in contrast to the rainfall of January-August, was less during the earlier period, 1850-1897. Therefore, the average rainfall was computed for March-April, May-June, April, May, June, July, August, and September. Only July and August showed greater

average rainfall for 1850-1897 than for 1898-1941. It was obvious at once that the greater rainfall of August aided by that of July caused the greater average rainfall of January-August during 1850-1897 at Santa Fe. In September, as a matter of interest, the averages swing back so that the figures are 1.58 inches for 1850-1897 and 1.66 inches

TABLE II.—Average rainfall (inches)

	March-July 1909-1941		January-August 1909-1941	
Chacon	10.34		15.80	
Black Lake	8.42		12.66	
Taos	5.96		8.83	
Taos Canyon	9.64		14.68	
Las Vegas	9.33		13.66	
Santa Fe	6.88		10.14	
Albuquerque	4.24		6.28	

	Santa Fe		Albuquerque	
	1850- 1897	1898- 1941	1850- 1897	1898- 1941
March-July	6.34	6.74	3.16	3.97
January-August	10.60	10.11	5.60	5.92
January-May	3.94	4.82	1.75	2.50
March-April	1.54	1.92	0.58	1.07
May-June	2.14	2.61	1.26	1.43
April	0.71	1.08	0.29	0.67
May	0.99	1.19	0.36	0.73
June	1.15	1.18	0.79	0.69
July	2.66	2.21	1.37	1.47
August	2.89	1.90	1.59	1.26
September	1.58	1.66	0.90	0.98

Albuquerque, 1850-1897, 27 years of record only.

for 1898-1941. This situation no doubt should be given emphasis: the average rainfall for the interval March-June began to increase somewhere near 1898 whereas that for the interval July-August decreased. Calculation shows that the average for March-June began to increase slowly just before the turn of the century and that the increase accelerated after 1909. The simultaneous increase and decrease of two sequential month-intervals is a point of importance in relation to the period of greatest tree growth within the season.

Table 12 gives the average year-to-year variation of rainfall arranged in two parts, the first of which sets out the variations of March-July and January-August rainfall for the period 1909-1941 at the several stations. In view of the differences in elevation, the average variation of the rainfall is of the same order of magnitude

TABLE 12.—*Rainfall*
Average year-to-year variation

	March-July 1909-1941		January-August 1909-1941	
Chacon	0.36		0.26	
Black Lake	0.38		0.29	
Taos	0.36		0.25	
Taos Canyon	0.28		0.22	
Las Vegas	0.41		0.34	
Santa Fe	0.35		0.27	
Albuquerque	0.63		0.45	
	Santa Fe		Albuquerque	
	1850- 1897	1898- 1941	1850- 1897	1898- 1941
March-July	0.42	0.33	0.79	0.60
January-August	0.39	0.27	0.63	0.44

TABLE 13.—*Rainfall*
Average departures

	March-July 1909-1941		January-August 1909-1941	
Chacon	0.22		0.17	
Black Lake	0.25		0.10	
Taos	0.27		0.20	
Taos Canyon	0.20		0.17	
Las Vegas	0.30		0.26	
Santa Fe	0.24		0.20	
Albuquerque	0.43		0.31	
	Santa Fe		Albuquerque	
	1850- 1897	1898- 1941	1850- 1897	1898- 1941
March-July	0.33	0.22	0.58	0.40
January-August	0.30	0.19	0.45	0.30

as that of the Holman Pass trees. The second part of the table shows the average variation of 1850-1897 to be greater than that of 1898-1941, which is no doubt to be expected because of the lower average rainfall of the earlier period. Even the interval January-August at Santa Fe has the same decrease in the later period.

Table 13 gives average rainfall departures. In the first portion of the table the departures for the rainfall of March-July and January-

August during the period 1909-1941 are given for the several stations. These average departures are noticeably less than the comparable values for the growth layers of the Holman Pass collection. In the second portion of the table the average departures of the period 1850-1897 are distinctly higher than those of the period 1898-1941. The contrast between the two periods stands thus: a lower average

TABLE 14.—*Holman Pass tree growth and Santa Fe rainfall—characteristics*

	1850-1897	1898-1941
<i>Average magnitude</i>		
Rainfall (inches)	6.34	6.74
Growth layers (mm.)		
G 10	1.53	1.70
II	2.26	1.96
7 (restricted)	1.99	1.83
<i>Average variation</i>		
Rainfall	0.42	0.33
Growth layers		
G 10	0.26	0.40
II	0.38	0.27
7 (restricted)	0.33	0.32
<i>Average departure</i>		
Rainfall	0.33	0.22
Growth layers		
G 10	0.32	0.36
II	0.34	0.30
7 (restricted)	0.35	0.31
<i>Average departure from mean variation</i>		
Rainfall	0.25	0.22
Growth layers		
G 10	0.132	0.148
II	0.204	0.118
7 (restricted)	0.130	0.105

rainfall during the earlier period is accompanied by a higher average variation and by a higher average departure. On the whole, such characteristics are to be expected.¹⁰

There remains, then, a comparison between the characteristics of the growth layers and those of rainfall for which the records of Santa Fe are used because of their length and continuity. Table 14 makes

¹⁰ Mixer, C. A., The rainfall year, Bull. Amer. Meteor. Soc., vol. 15, pp. 22-23, 1934; Williamson and Clark, Variability of annual rainfall in India, Geogr. Rev., vol. 21, pp. 675-676, 1931.

these comparisons using March-July rainfall. An increase in average rainfall (as between 1850-1897 and 1898-1941) is accompanied by an increase of average growth-layer thickness on dry sites (group 10) and by a decrease on wet sites (group 11); an increase in rainfall giving a decrease in its average variation is accompanied by an increase of average variation among growth layers from dry sites and by a decrease among growth layers from wet sites; an increase in rainfall giving a decrease in its average departure is accompanied by an increase of average departure among growth layers from dry sites and by a decrease among growth layers from wet sites; and an increase in rainfall giving a decrease in its average departure from mean variation is accompanied by an increase of average departure from mean variation among growth layers from dry sites and by a decrease among growth layers from wet sites.

In other words, changes of average variation, average departure, and average departure from mean variation among growth layers from wet sites follow the changes of the same features in the rainfall whereas the growth layers from dry sites react in the opposite direction. The case is reversed as regards changes in growth-layer thicknesses: the growth layers from the dry sites follow the changes in average rainfall amounts. However, as discussed under the study of growth layers, two trees, HPC 1 and 7 of group 10, determine the characteristics of the group. Their elimination from the complete record leaves a homogeneous group consisting of the other two trees of group 10 and all trees of group 11 (HPC 8 is not included because its sequence is too short). This group of six trees, group 7 (restricted), is conformable within itself, and the changes in its characteristics from 1850-1897 to 1898-1941 agree with those of Santa Fe rainfall.

Nevertheless, there remains the problem of why the average variation of the dry-site trees increased with a decrease of average variations in rainfall during 1898-1941. Calculation of the average variation of rainfall for different months and month-intervals shows that only April and May increased their average variations during the period 1898-1941. It might be, therefore, that the dry-site trees were more influenced by April-May, or spring, rainfall than the wet-site trees were. Or the problem may concern limiting factors and optimum or near optimum soil-moisture conditions in that the wet-site trees grew under conditions where the trees responded directly and consistently to changes in rainfall.

It is clear that the relations of tree growth to rainfall are highly complex not by themselves alone but also by the interplay of the entire range of growth factors, a circumstance emphasized by plant physiologists and ecologists.¹¹ The problem calls for much more work—it is far from finished. The observational method of field selection and laboratory analysis remains secondary to direct experiment on growing trees under controlled conditions.

In any event, the present work comparing tree growth and rainfall characteristics strongly suggests that trees selected from certain sites and from the proper rainfall or soil-moisture zone can be sensitive indicators of rainfall changes through the use of average variation, average departure, and average departure from mean variation.

CORRELATION OF TREE GROWTH AND RAINFALL

Range of tests.—Fairly extensive correlations were made between tree growth and Chacon and Santa Fe rainfall both for groups and for individual trees. The trend method was applied in its complete form until it was determined that variations of 1 or 2 years did not unduly distort the results. In addition to the more extensive correlations, selected tests were made between tree growth and the records of other rainfall stations.

Tree growth (groups) and Chacon rainfall.—Groups 1 to 9 were correlated with Chacon rainfall for the month-intervals shown in table 15. However, the table includes only those groups which were most significant.

The table shows that correlations with March-July and January-August rainfall are the highest, and of these two intervals March-July is the more important. July rainfall is necessarily included as is indicated by the lower correlations of March-June. Of the 5 months, March-July, the rainfall of May-June is more important to tree growth than that of March-April and the rainfall of April is of less importance than that of May, June, or July. Apparently tree growth, as represented by the trees selected, responds directly to the rain which falls during and the several weeks immediately preceding the actual growing season.

The most striking fact obvious at first sight is the correlation between group 7 (all trees) and March-July rainfall, the trend coefficient being 0.965 and the ratio of opposed trends 0.12. A trend ratio of 0.12 means that the trend of rainfall was opposite to the trend

¹¹ Bot. Rev., vol. 7, pp. 651-655, 1941.

of tree growth for 4 years out of 32 of variation. Of these opposite trends that for 1910 contains 84 percent of the numerical disagreement and, if 1910 be eliminated, the trend coefficient rises to 0.994. A comparison of the rainfall among all seven stations with the tree growth of group 7 for the 4 years of opposite trend, 1910, 1912, 1913,

TABLE 15.—*Correlation of tree groups and Chacon rainfall*

*Trend coefficients and ratios of opposed trends
1909-1941*

	G 4	G 5	G 7	G 9	G 10	G 11
Mar.-July	0.93 (0.22)	0.82 (0.31)	0.965 (0.12)	0.88 (0.19)	0.96 (0.16)	0.92 (0.22)
Jan.-Aug.	0.92 (0.16)	0.73 (0.31)	0.95 (0.19)	0.88 (0.25)	0.94 (0.22)	0.91 (0.28)
Mar.-June	0.85 (0.28)	0.82 (0.28)	0.89 (0.16)	0.77 (0.28)		
May-Aug.	0.80 (0.25)	0.68 (0.37)	0.80 (0.28)	0.66 (0.28)		
May-June	0.73 (0.31)	0.70 (0.34)	0.72 (0.28)	0.49 (0.34)		
Jan.-May	0.72 (0.25)	0.32 (0.44)	0.70 (0.28)	0.62 (0.41)		
Nov.-May	0.71 (0.23)	0.26 (0.42)	0.68 (0.26)	0.59 (0.39)		
Mar.-Apr.	0.50 (0.41)	0.44 (0.44)	0.55 (0.37)	0.52 (0.50)		
May-July	0.84 (0.22)	0.71 (0.31)	0.85 (0.19)	0.71 (0.25)		
April	0.04 (0.47)	0.20 (0.47)	0.09 (0.56)	0.14 (0.56)		
May	0.75 (0.25)	0.34 (0.44)	0.64 (0.34)	0.27 (0.41)		
June	0.42 (0.47)	0.79 (0.25)	0.59 (0.37)	0.54 (0.44)		
July	0.62 (0.41)	0.48 (0.50)	0.66 (0.37)	0.63 (0.37)		
August	0.39 (0.37)	0.33 (0.44)	0.35 (0.41)	0.27 (0.41)		

and 1931, shows that from one to three stations disagree with the remainder in each case. The 5 years of greatest parallel variation in the complete record have only one station disagreeing with the remainder for 1 year. Where the parallel variations are of small amount the different rainfall stations are much at variance with each other for all years. Therefore, it is possible to speculate that the rainfall at the site of the trees actually agreed with tree growth; however,

the data at Chacon are the closest legitimate record and must be retained as they stand.

The quality of the correlation between tree growth and March-July rainfall at Chacon for the 33-year interval (table 15) is all that can be ecologically expected considering the distance between Holman Pass and Chacon, and considering the quality of the correlations between the rainfall of two stations approximately as far apart as Holman Pass and Chacon. This suggests that the trees as a group follow with a high degree of accuracy the fluctuations of rainfall at the immediate site.

In general, group 7 shows slightly higher correlations than the others and group 5 slightly less; otherwise there is little choice among them. Group 4, the closest to Chacon, has a very slight advantage over group 9, and both have higher correlations than group 5, which is ecologically less similar to the other two than they are between themselves. In the case of groups 10 and 11, the former (from the drier sites) has a slightly higher correlation than the latter although not sufficiently so to justify any conclusions. Group 7, containing all trees, possesses slightly better correlation than group 7 (restricted), the values for March-July being 0.95 and (0.28) and for January-August 0.94 and (0.19).

Figure 4 shows Chacon rainfall for March-July compared with tree growth of the several pertinent groups.

The charted correlations of group 7 with Chacon rainfall in figure 6 indicate in general that the absence of summer rainfall and the presence of winter rainfall militate against high agreement. It is neither spring rainfall alone nor spring combined with winter rainfall which gives highest correlations but spring added to early and midsummer rainfall.

Tree growth (individual trees) and Chacon rainfall.—Individual trees were correlated with the two rainfall intervals of March-July and January-August (table 16). The results are to be expected, no doubt, in view of the former group correlations. In general, the trees agree a little better with March-July than with January-August rainfall. Tree HPC 3, a foxtail pine, has the highest correlation and HPC 9, a ponderosa pine, has the lowest. However, HPC 5, a Douglas fir, runs a close second to HPC 9. As a matter of fact, tree HPC 3, which stands between HPC 1 and 2, could be used as a fair substitute for group 7. Ponderosa pines have no advantage over the other species. On the whole, the trees east of the Pass correlate better than those on the Pass and these latter slightly better than those

TABLE 16.—*Correlation of Holman Pass trees and Chacon rainfall*
Trend coefficients and ratios of opposed trends
 1909-1941

HPC	March-July	January-August
1.....	0.92 (0.25)	0.90 (0.31)
2.....	0.89 (0.25)	0.90 (0.25)
3.....	0.92 (0.19)	0.92 (0.12)
4.....	0.89 (0.25)	0.83 (0.25)
5.....	0.81 (0.34)	0.68 (0.41)
6.....	0.78 (0.31)	0.77 (0.31)
7.....	0.90 (0.22)	0.87 (0.34)
8.....	0.88 (0.22)	0.90 (0.22)
9.....	0.51 (0.28)	0.62 (0.34)

HOLMAN PASS TREE GROWTH AND CHACON PRECIPITATION

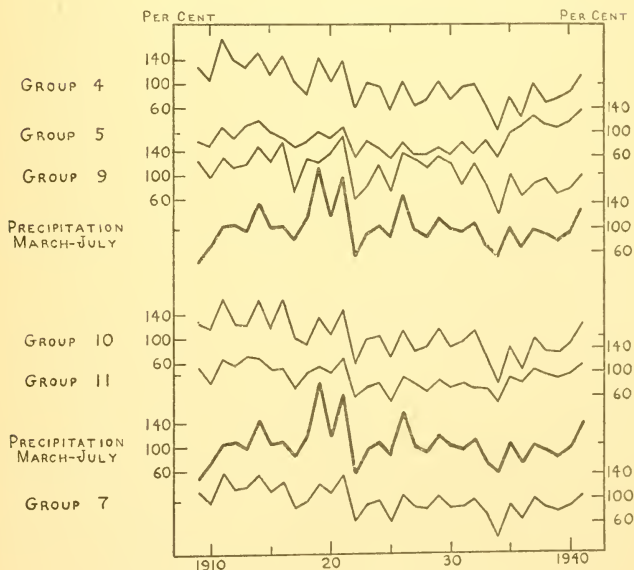


FIG. 4.—Graphs of tree growth and rainfall 7 miles distant, in raw percentages. Group 4, east of Pass; group 5, on Pass; group 9, west of Pass; group 10, normal or dry-site trees; group 11, wet-site trees; and group 7, all trees.

west of the Pass although there are individual exceptions. The most striking contrast appears between the trees from the drier sites, group 10, and those from the wetter, group 11.

In summary, it is rather clearly evident, first, that a group is superior to single trees for a record of rainfall variations and, second, that the variations shown among the trees in table 16, especially in the ratios of opposed trends, emphasize the influence of what has previously been referred to as microsite factors. A union of several tree records apparently generalizes the record of response to rainfall. When consideration is given the facts that the trees do differ from each other by an amount to be expected over a short term, in view of the variations among different rainfall records themselves; that the trees are several miles from Chacon; that rainfall is but one growth factor in a complex; and that rainfall itself is rather remote from its incorporation into the hydrostatic system of the plant, the correlations not only between rainfall and tree groups but also between rainfall and individual trees are surprisingly high for the period 1909-1941.

Tree growth (groups) and the rainfall of other stations.—Certain groups were correlated with the rainfall of the stations at Black Lake, Taos Canyon, Taos, and Albuquerque. The results for four of the groups are shown in table 17. Before continuing it should be mentioned that these particular correlations were not included to demonstrate that tree growth can be compared to distant rainfall with significant results or to indicate favor for such correlations. They are shown rather because they appear to indicate that detailed influence of specific rainfall subsides with distance and only general variations common to the region remain. With ratios of opposed trends ranging from 0.22 to 0.50, tree growth in one locality gives a poor picture of rainfall variations at a distance.

On the one hand, correlations with March-July rainfall, the best in the case of Chacon, are mixed and poor; it is difficult to read any significance into them. On the other hand, correlations with the more general interval of January-August rainfall are higher and more consistent and emphasize the regional regime. Even so, the number of instances in which the trees respond in a direction opposite to the rainfall trends militates against the use of tree growth, as exemplified by the Holman Pass collection, for an accurate gauge of regional rainfall variations from season to season. This is not to say that smoothing would not bring out general trends if the influence of other

TABLE 17.—*Correlation of tree groups and rainfall
Trend coefficients and ratios of opposed trends
1909-1941*

	G 4		G 5		G 9		G 7	
	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.
Black Lake	0.32 (0.41)	0.78 (0.31)	0.36 (0.44)	0.75 (0.34)	0.33 (0.50)	0.80 (0.28)	0.37 (0.44)	0.86 (0.22)
Taos Canyon	0.79 (0.37)	0.79 (0.28)	0.79 (0.31)	0.71 (0.38)	0.75 (0.41)	0.89 (0.28)	0.84 (0.34)	0.89 (0.22)
Taos	0.74 (0.25)	0.65 (0.31)	0.62 (0.34)	0.66 (0.34)	0.66 (0.28)	0.80 (0.28)	0.79 (0.22)	0.80 (0.28)
Albuquerque	0.77 (0.28)	0.86 (0.28)	0.79 (0.28)	0.81 (0.41)	0.61 (0.37)	0.77 (0.37)	0.81 (0.31)	0.88 (0.31)

factors were eliminated and if the trees were properly selected from the region and from the proper zone.

Further to test the general relationships, the March-July and January-August rainfall of Chacon, Las Vegas, Taos Canyon, and Black Lake were combined for the period 1909-1941 and correlated with group 7. The results follow.

	Raw percentages	Smoothed percentages
March-July	0.95 (0.19)	0.96 (0.22)
January-August	0.96 (0.16)	0.86 (0.31)

Although these values are high no advantage results from the use of the combined rainfall. The raw percentage values for group 7 (restricted) correlated with combined rainfall of March-July are 0.955 and (0.22), and of January-August rainfall 0.955 and (0.12).

An analysis of table 17 shows, further, that altitude in general has some effect: the correlations are slightly higher for group 9, which is closer to the average elevation of the rainfall stations.

TABLE 18.—*Correlation of tree groups and Las Vegas rainfall
Trend coefficients and ratios of opposed trends*

	March-July		January-August	
	1893-1941	1910-1941	1893-1941	1910-1941
G 4	0.78 (0.33)	0.93 (0.28)	0.73 (0.20)	0.89 (0.16)
5	0.73 (0.31)	0.81 (0.27)	0.66 (0.22)	0.73 (0.22)
9	0.59 (0.47)	0.64 (0.44)	0.63 (0.39)	0.63 (0.37)
7	0.79 (0.35)	0.91 (0.31)	0.73 (0.27)	0.86 (0.25)

Trees HPC 3, 5, 7, and 9 were correlated with the stations listed in table 17. The results are similar to those for the groups in the table except for somewhat lower values.

Tree growth and Las Vegas rainfall.—With the exception of Santa Fe, Las Vegas has the longest rainfall record of any station in the general area but it is some 37 miles distant from Holman Pass and 3,000 feet lower. Table 18 gives the trend coefficients and the ratios of opposed trends between tree growth and Las Vegas rainfall for the intervals and years noted. On the whole, the correlations

with March-July rainfall slightly exceed those with January-August. They decrease in quality with distance; that is, correlations of group 4 (east of Pass) are highest and those of group 9 (west of Pass) are lowest.

The most striking feature of the table is the decided increase in correlation of the period 1910-1941 over the period 1893-1941. During the later period (1910-1941) the trees follow more closely the variations in rainfall as recorded at Las Vegas.

Tree growth and Santa Fe rainfall.—Although Santa Fe is distant some 40 miles from Holman Pass it is worth while, because of the length of record, to compare Santa Fe rainfall with tree growth in order to determine if the quality of correlation varied throughout the length of that record. Nine tree groups were correlated with all rainfall intervals for the periods 1850-1897 and 1898-1941 separately.

Data most pertinent to the study appear in table 19, which gives the trend coefficients and ratios of opposed trends for the periods mentioned above. The remainder of the data, not shown, simply corroborate what the table itself shows. On the whole, tree growth correlates considerably better with March-July than with January-August rainfall. Here, however, in contrast with Chacon rainfall, groups 4, 5, and 7 agree somewhat better with March-June rainfall.

General correlations are fair; they possess little value except to show a regional tendency toward similarity during a portion of the years. This appears in table 20 where trend coefficients for the period of 1850-1941 vary from 0.52 to 0.67 and the ratios of opposed trends from 0.24 to 0.37. The values for group 7 are 0.65 for the trend coefficient and 0.35 for the ratio of opposed trends. Thus, a case of 35 opposite trends against 65 parallel gives neither high nor dependable correlation. Surprisingly, the trees from the wetter sites, group 11, compare most favorably with Santa Fe rainfall for the period 1850-1941. In view of the quality of correlation between Holman Pass tree growth and Chacon rainfall on the one hand and between Chacon and Santa Fe rainfall on the other, the correlation between tree growth and Santa Fe rainfall possesses values consistent with the relative distances.

Figure 5 shows Santa Fe rainfall for March-July compared with tree growth of the several pertinent groups. Figure 6 shows the correlations in charted form. For the period 1898-1941 the trend of the graph resembles that for the Chacon correlations. It contrasts notably with the graph for the period 1850-1897, where the emphasis seems to be on spring rainfall.

TABLE 19.—*Correlation of tree groups and Santa Fe rainfall*
Trend coefficients and ratios of opposed trends

	G 4		G 5		G 9		G 7	
	1850-97	1898-1941	1850-97	1898-1941	1850-97	1898-1941	1850-97	1898-1941
Mar.-July	0.51 (0.47)	0.67 (0.27)	0.36 (0.40)	0.83 (0.20)	0.44 (0.40)	0.70 (0.32)	0.51 (0.43)	0.77 (0.27)
Jan.-Aug.	0.24 (0.47)	0.70 (0.34)	0.01 (0.49)	0.77 (0.25)	0.05 (0.49)	0.76 (0.30)	0.12 (0.51)	0.86 (0.25)
Mar.-June	0.61 (0.40)	0.67 (0.27)	0.53 (0.30)	0.79 (0.23)	0.45 (0.42)	0.62 (0.32)	0.64 (0.32)	0.73 (0.27)
May-Aug.	0.09 (0.60)	0.72 (0.32)	0.10 (0.49)	0.67 (0.23)	0.00 (0.51)	0.64 (0.32)	0.04 (0.55)	0.79 (0.23)
May-June	0.38 (0.45)	0.68 (0.39)	0.47 (0.34)	0.70 (0.30)	0.16 (0.40)	0.59 (0.39)	0.40 (0.36)	0.72 (0.34)
Jan.-May	0.51 (0.40)	0.61 (0.18)	0.21 (0.38)	0.72 (0.20)	0.18 (0.47)	0.58 (0.27)	0.35 (0.43)	0.62 (0.23)
Nov.-May	0.36 (0.27)	0.68 (0.16)	0.04 (0.37)	0.73 (0.23)	0.12 (0.39)	0.60 (0.34)	0.17 (0.39)	0.69 (0.25)
Mar.-Apr.	0.52 (0.36)	0.32 (0.39)	0.30 (0.34)	0.44 (0.41)	0.63 (0.45)	0.34 (0.48)	0.61 (0.32)	0.34 (0.50)

The most important, perhaps, and certainly the most startling information yielded by tables 19 and 20 is the great increase in the quality of correlation from the period 1850-1897 to the period 1898-1941. Table 20 shows this in abbreviated form for March-July rainfall, which appears to have most influence on tree growth. In addition, table 20 includes the period 1910-1941. It is to be noted that correlation is higher for 1910-1941 than for 1898-1941; in other words, there is a general increase in correlation toward recent years. Of all the groups, numbers 5 and 11, containing trees from the wetter sites, show not only the greatest increases but also the highest corre-

TABLE 20.—*Correlation of tree groups and Santa Fe rainfall*
Trend coefficients and ratios of opposed trends
March-July rainfall

	1850-1897	1898-1941	1910-1941	1850-1941
G 4	0.51 (0.47)	0.67 (0.27)	0.77 (0.22)	0.61 (0.37)
5	0.36 (0.40)	0.83 (0.20)	0.87 (0.16)	0.52 (0.31)
9	0.44 (0.40)	0.70 (0.32)	0.71 (0.25)	0.58 (0.36)
7	0.51 (0.43)	0.77 (0.27)	0.85 (0.22)	0.65 (0.35)
10	0.51 (0.43)	0.69 (0.25)	0.76 (0.19)	0.62 (0.34)
11	0.42 (0.38)	0.81 (0.30)	0.90 (0.22)	0.67 (0.24)
7 (restricted) ..	0.46 (0.45)	0.82 (0.27)	0.89 (0.22)	0.63 (0.36)

lations for the periods 1898-1941 and 1910-1941. And of these two groups, number 5, composed of trees on the Pass, exceeds even group 11. Group 10, in contrast, containing trees from the drier sites, and group 4 exhibit the least increases. Table 11, giving the March-July rainfall of Santa Fe for the periods 1850-1897, 1898-1941, and 1910-1941, shows the rainfall to have been 6.34, 6.74, and 6.88 inches, respectively, for those periods. Furthermore, the low incidence of parallel trends, growth layer to growth layer, among the trees prior to 1897 as compared with the years following 1897 (as noted above under study of growth layers), and the lower correlations between trees and groups (table 2), suggest emphatically that the above phenomena are closely related.

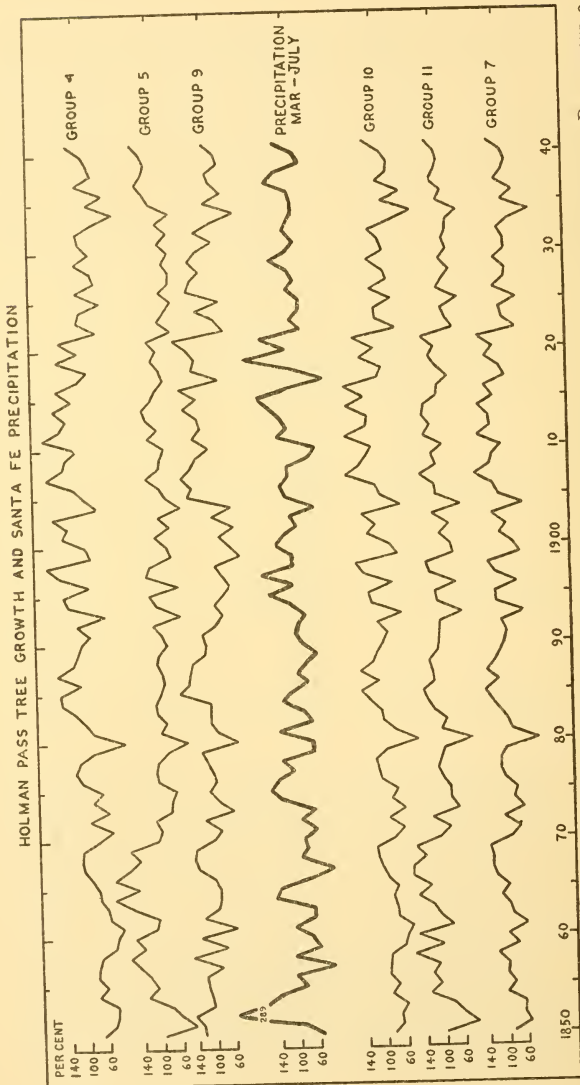


FIG. 5.—Graphs of tree growth and rainfall 40 miles distant, in raw percentages. Group 4, east of Pass; group 5, on Pass; group 9, west of Pass; group 10, normal or dry-site trees; group 11, wet-site trees; and group 7, all trees.

Table 19, as stated heretofore, shows a higher correlation for 1898-1941 than for 1850-1897. This is true for all month-intervals except for March-April which has lower correlations in groups 4, 7, and 9 for 1898-1941. Apparently March-April rainfall had greater influence on tree growth during the earlier period than during the later. Group 5 did not conform except in the ratio of opposed trends. An examination of the temperature records readily available gives table 21.

Obviously, a thermochemical or thermophysiological approach to temperature problems via direct experimental evidence in conjunction

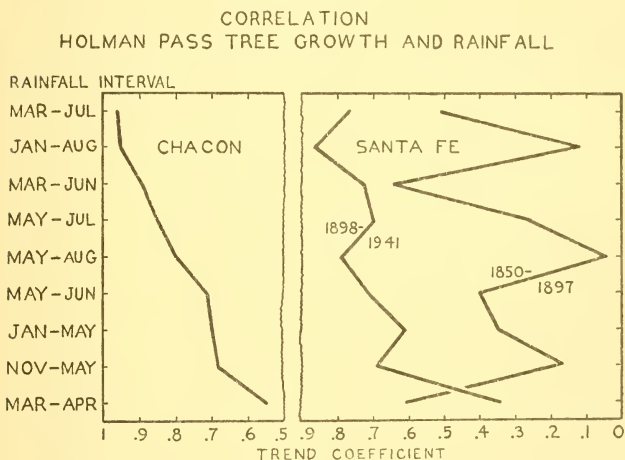


FIG. 6.—Charted correlations between tree growth of group 7 and rainfall of various month intervals.

with exact knowledge of growth initiation would give a much better idea of relationships among temperature, soil moisture, and growth. However, table 21 shows that for March, April, and May the average temperatures and the average maxima were somewhat higher for the period 1874-1897 and progressively lower thereafter except in the case of May when they were slightly higher again during 1910-1930. June follows the same pattern but in a less decided fashion. It is perhaps not illogical to speculate that with higher temperatures during 1874-1897 growth began earlier in the spring and was therefore influenced by March-April rainfall to a greater extent than after 1897. This may be linked up with the discussion, under the preceding section, of the parallel increase of average variation in dry-site trees and

April-May rainfall for the period 1898-1941 over that of 1850-1897. Again, figure 6, showing the charted correlations of group 7 with Santa Fe rainfall for 1850-1897, shows the emphasis to be on spring rainfall. These relationships emphasize the multiple nature of growth factors and the complexity of the problems involved.

Before the contrasts between the periods 1850-1897 and 1898-1941 are summarized, mention should be made of two points, one having to do with the incidence of opposed trends and the other with cumulative variations. First, the incidence of opposed trends was calculated for each 10-year interval for several of the groups against the various rainfall intervals. In the case of groups 7, 10, and 11 compared with March-July rainfall the incidence of opposed trends shows a general decline from early to recent years. The same is

TABLE 21.—*Santa Fe temperatures*

	1874-1897	1898-1930	1910-1930
March			
Average	39.9	39.4	39.0
Maximum	51.4	50.5	50.1
Minimum	28.0	28.4	27.9
April			
Average	47.4	46.75	46.5
Maximum	60.0	58.45	58.2
Minimum	34.76	35.1	34.8
May			
Average	56.5	55.1	55.5
Maximum	69.4	67.2	67.7
Minimum	43.5	43.0	43.3

true, in fact, for all rainfall intervals except that for March-April in which the incidence increases from 1850 to 1941, thus agreeing with the decrease of tree growth-rainfall correlation. Second, figure 7 gives the plotted cumulative variations of Santa Fe March-July rainfall and certain tree groups. Groups 5 and 11 and groups 4 and 10 were each combined into one graph because the separate graphs very nearly coincided. If groups 4 and 5 had been omitted there would have been no change. The graphs illustrate the close correspondence between the variations of Santa Fe rainfall and the variations of tree growth as represented by group 11 which contains the trees from the wetter sites.

The various tables have brought out the contrasts between the periods 1850-1897 and 1898-1941. These may now be summarized in respect to March-July rainfall at Santa Fe. In so far as data are

available, the rainfall records of Albuquerque and Las Vegas corroborate the results obtained by the use of Santa Fe rainfall.

For the rainfall of the period 1898-1941, against the period 1850-1897: amount of rainfall increased; and average variation, average departure, and average departure from mean variation decreased.

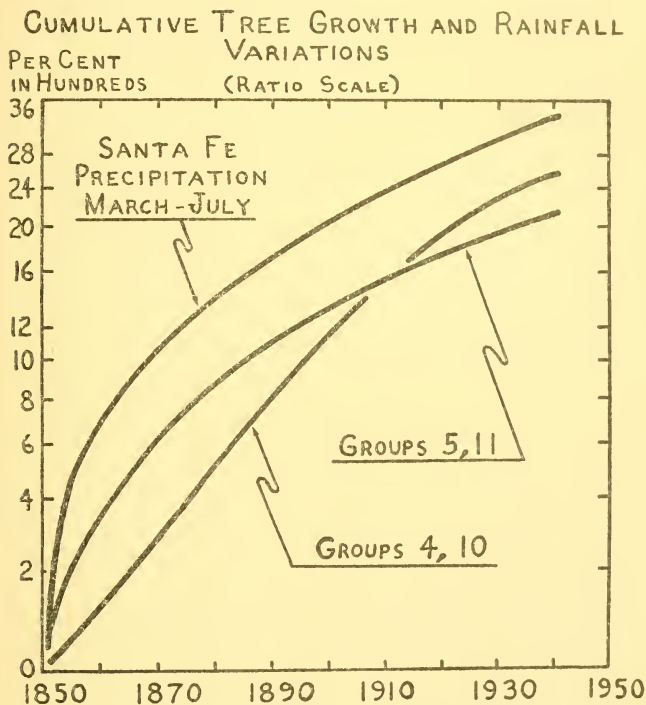


FIG. 7.—Cumulative variations of tree growth and rainfall. Trees in groups 5 and 11 were from wet sites and those in groups 4 and 10 chiefly from dry sites.

For group 11 contrasted in the same manner: average variation, average departure, and average departure from mean variation decreased; and correlation with rainfall increased to an extent comparable to that with Chacon rainfall considering the much greater distance.

For group 10 contrasted in the same manner: average variation, average departure, average departure from mean variation, and correlation with rainfall increased.

For group 7 contrasted in the same manner: average variation and average departure increased; average departure from mean variation decreased very slightly; correlation with rainfall increased; and internal agreement of the trends among the several trees increased.

For group 7 (restricted) contrasted in the same manner: average variation, average departure, and average departure from mean variation decreased.

The substance of the above summary is that the characteristics of group II, made up of wet-site trees, and group 7 (restricted) agree with those of rainfall whereas most of the characteristics of group 10 and group 7 disagree except for correlation with rainfall. Also, *intra-correlation on the wood rises in quality with greater rainfall.*

Obviously, these findings must be translated into a method whereby study of the wood alone can be made to reveal changes in rainfall. Two of the trees from the drier sites (in group 10) for some reason reacted oppositely in comparison with the remainder of the collection and when combined into group 7 (all trees) overbalanced the influence of the remainder save for the one characteristic, average departure from mean variation. It is clear in respect to the Holman Pass trees that agreement of variation among the trees rises with increased rainfall. Such increase in rainfall would be expected to lessen the variation of rainfall within short distances on the ground as it affects growth and thus permit greater agreement among the trees. This is well shown by table 2 especially among groups. Reasoning from a knowledge of rainfall characteristics one can expect average variation to decrease with increase of rainfall.

Therefore, in regard to a study of the wood alone for evidence of rainfall changes, the Holman Pass collection suggests the use of the following methods: (1) the amount of agreement in directional variation, including correlation and trend parallelism, among the trees themselves; (2) the change in average variation, average departure, and average departure from mean variation among growth layers of trees grown under conditions, or in a zone, at least as moist as those for group II or for group 7 (restricted).

RÉSUMÉ

In bringing together a résumé of results it is well to recall the several aspects of the study: The site chosen extended from well

within the Transition Zone up into the Canadian; the number of trees sampled was limited to nine; the collection contained trees of four different species and comprised three groups geographically and hypsometrically; the trees, in the field, divided themselves ecologically into two groups, the one (group 10) representing normal water relationships without excess drainage to or from the trees, and the other (group 11) representing slightly above-normal water relationships for the general locality; the samples consisted of increment cores—essentially one radius to represent the entire volume growth of a tree; site factors were judged solely by inspection on the spot; the terrain was mountainous; the nearest rainfall station, Chacon, was 7 miles distant at an elevation intermediate between the highest and lowest trees; and analyses were based on raw (i.e., unsmoothed) data.

The present study brings out many points in summary which are distinctly secondary to the main objectives. In the present stage of investigations of this type, all points, secondary as well as primary, are highly suggestive only. It remains to be determined if the principles and methods here used in the field and in the laboratory are of more general application. Only then can growth-layer sequences be interpreted in the absence of nearby rainfall stations. Obviously, we must know how trees reveal their ecologic information before we can determine what they tell.

Study of growth layers.—1. Cross-dating of high quality is not a necessary prerequisite to the correlation of growth-layer thicknesses and rainfall, and its nearly total absence does not indicate a lack of significant response on the part of the trees to rainfall variations.

2. The presence or absence of high-quality cross-dating does not necessarily constitute the criterion whereby a tree record is included in a group average or excluded from it. Some other criterion should be applied for the elimination of certain growth-layer sequences after the collection is brought to the laboratory, if such elimination is attempted with justification.

3. Partial disagreement among the various trees, growth layer to growth layer, emphasizes a definite localization of site factors to each tree.

4. Disagreement among the trees increased with increasing distance, distance measured in yards rather than in miles.

5. Intergroup correlations (of groups 4, 5, and 9) were merely fair, not at all striking. They show a dual influence of site and distance.

6. In so far as the collection from Holman Pass is concerned, the nature of the species is clearly subordinate to the influence of site.

7. Correlations among different trees and among different groups were distinctly lower for the period 1850-1897 than for the period 1898-1941.

8. A simultaneous comparison of trend among all trees yielded 9 complete agreements among the trees during the 48 years of the period 1850-1897 and 15 during the 44 years of the period 1898-1941.

9. For group 10 (dry sites) average year-to-year variation, average departure, and average departure from mean variation increased whereas for group 11 (wet sites) they decreased for the period 1898-1941 in contrast with the period 1850-1897. However, the average departure of two of the trees in group 10 actually agreed with group 11.

10. The average departure from mean variation of group 7 (restricted) and group 7 itself decreased for the period 1898-1941 in contrast with the period 1850-1897.

11. A study and comparison of the growth-layer sequences emphasize the role of site factors local to each tree and the striking contrast of characteristics between the two periods, 1850-1897 and 1898-1941.

Study of rainfall characteristics.—1. Chacon rainfall was correlated with that of the other six stations for eight different month-intervals. Trend coefficients ranged from 0.61 to 0.99 and ratios of opposed trends from 0.41 to 0.09.

2. No clear-cut pattern emerged from this correlation between Chacon and the other stations. However, the values declined with the presence of summer rainfall and with an increase in the number of months in the month-intervals. Within the area from which rainfall stations were drawn, distance from Chacon made little difference in the variations among the several stations.

3. The average trend coefficient between Chacon and the other stations was approximately 0.89 and the ratio of opposed trends 0.23. If the trees were responding directly to the rain falling at the immediate site, they may be expected to correlate with Chacon rainfall to a degree equaling or slightly exceeding (because of the distance involved) the average of the correlations between Chacon and the other rainfall stations.

4. Correlations among the eight different month-intervals at Chacon ranged from -0.33 to 0.99 for the trend coefficients and from 0.66 to 0.06 for the ratio of opposed trends. Such divergences demanded that tree growth be tested against the full series of month-intervals.

5. If tree growth shows high correlation with a certain rainfall interval, as March-July, and if that interval has high correlation with a second one, as January-August, then tree growth may be expected to show high correlation with the second interval even though part of the rainfall of the longer interval may not influence growth.

6. Within limits, maximum correlation combined with minimum-length month-intervals should be the focus of critical information on the response of trees to rainfall.

7. The average March-July rainfall at Santa Fe was higher during the period 1898-1941 than during the period 1850-1897 and higher during the period 1909-1941 than during the period 1898-1941.

8. Average year-to-year variation, average departure, and average departure from mean variation of March-July rainfall at Santa Fe was less during the period 1898-1941 than during the period 1850-1897.

9. For the contrasted periods 1850-1897 and 1898-1941, the characteristics of the dry-site trees ran counter to those of rainfall whereas those of the wet-site trees ran parallel.

10. When a criterion of conformity, based on average departure, was applied and the two trees not conforming were eliminated, the characteristics of the resultant group 7 (restricted) followed those of rainfall.

Correlation between tree growth and rainfall.—1. Correlations between tree growth and rainfall of Chacon, the nearest station, were highest for the rainfall of the March-July interval of the same year. This is consistent with the principle of maximum correlation with minimum-length month-interval. The next best correlation, with January-August, was also high, but the reason was held to be the rather high correlation between that interval and March-July.

2. The growth of the trees composing the Holman Pass collection correlated directly with the precipitation which fell immediately before and during the season of greatest growth.

3. Correlation between the Holman Pass trees and Chacon March-July rainfall, based on raw (unsmoothed) data, attained the following remarkably high values: a trend coefficient of 0.965 and a ratio of opposed trends of 0.12.

4. The accumulated evidence points rather clearly to the conclusion that the trees respond very nearly 100 percent to fluctuations of rainfall at the immediate site.

5. Correlations between individual trees and Chacon rainfall were lower than those for groups. A few were surprisingly high.

6. The nature of the species appeared to make little difference in the quality of correlations.

7. The variations among the trend coefficients and ratios of opposed trends of individual trees emphasized again the localized influence of site factors on the single tree, the so-called microsite factors.

8. Correlations between tree growth and rainfall of stations other than Chacon gave mixed and rather poor results. Certain regional tendencies remained, but they are of little or no value.

9. Correlations between tree growth and Las Vegas rainfall were higher for the period 1910-1941 than for that of 1893-1941.

10. General correlations between tree growth and Santa Fe rainfall were fair to poor and have little value as regards season-to-season fluctuations. Such results were to be expected in view of the distances involved and the areal differences in rainfall as measured from station to station.

11. The higher the correlations were among the trees themselves, the higher their correlation with rainfall. An increase in amount of rainfall was accompanied by greater agreement among the trees.

12. The most important information brought out by the correlation of tree growth and Santa Fe March-July rainfall for the periods 1850-1897, 1898-1941, and 1910-1941 was this: The quality of the correlations was lowest for the first period and highest for the last. All tree groupings conformed. The amounts of March-July rainfall at Santa Fe showed a similar increase for the three periods.

13. In the above correlations, the trees from the wetter sites showed not only the highest correlations but also the greatest increases.

14. A change in temperature that affected the time of growth initiation in the spring probably shifted the month-interval of rainfall to which the trees responded.

15. Trees from drier sites, as a group, were poor recorders of changes in rainfall characteristics; individually, two out of the four conformed in part to the wet-site group.

16. A summary of changes from the period 1850-1897 to the period 1898-1941 follows:

In March-July rainfall:

Average variation, average departure, and average departure from mean variation decreased with an increase in average rainfall.

In tree growth:

Among all trees, internal agreement increased.

For dry-site trees, group 10, average variation, average departure, and average departure from mean variation increased.

For all trees, group 7, average variation and average departure increased whereas average departure from mean variation decreased.

For wet-site trees and group 7 (restricted), average variation, average departure, and average departure from mean variation decreased, thus agreeing with changes in March-July rainfall.

CONCLUSIONS

A study of the Holman Pass collection, which came partly from the Transition and partly from the Canadian Life Zones, permits two general conclusions.

First, the evidence indicates rather clearly that variations in tree growth follow variations of March-July rainfall from year to year very nearly 100 percent at the immediate site of the trees.

Second, the evidence strongly suggests that changes of internal agreement among the trees and changes of average variation, average departure, and average departure from mean variation can be used as a method to reveal changes in rainfall through the years where amount of rainfall, and hence derived soil moisture, approximately equals that present at the location of the dominant members of the Holman Pass collection.







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