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TARDIGRADA FROM WESTERN NORTH AMERICA

With Emphasis on the Fauna of California

BY

ROBERT O. SCHUSTER and ALBERT A. GRIGARICK

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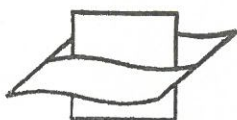
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INTRODUCTION

TARDIGRADES ARE VERY COMMON in nature and large numbers of many species often can be collected in a short period of time at almost any locality. Preparation of material for systematic study is simple, as may be the maintenance of cultures. Tardigrades have been known for nearly 200 years and have been considered in more than 300 papers. However, the fauna of North America has received little attention, and that of western North America almost none at all.

The present study began largely as a result of our annoyance with the difficulty met in recognizing local species and ended with our satisfaction in becoming familiar with most of them. Our hope in presenting the results of this study is that easy and relatively certain determination of the western species will be possible for all interested persons.

We encountered difficulty in securing some literature, even at large institutions. However, a paper by Riggins (1962) gives, in English, a summary of arguments for considering the Tardigrada as a phylum. A recent monograph by Ramazzotti (1962) presents the most recent and complete systematic treatment. Apparently little has been added in recent years to the knowledge of tardigrade embryology, physiology, or morphology. Early work in these fields is reviewed in English (Riggins, 1962), French (Cuénot, 1932), German (Marcus, 1927, 1936), Italian (Ramazzotti, 1962), and Spanish (Rodríguez-Roda, 1952). An interesting review of anabiosis was presented by Keilin (1959).

The phylum Tardigrada consists of 23 genera, about 278 species and 29 infraspecific variants. Four large genera contain the majority of the species: *Echiniscus* has 84 species and 14 infraspecific categories, *Hypsibius* has 84 and 7, *Macrobiotus* 60 and 4, and *Pseudechiniscus* 22 and 4. Twelve of the remaining genera are monotypic.

About forty authors have contributed to the naming of tardigrade species, with Bartoš, Marcus, Murray, Richters, Thulin, and Mihelčič responsible for 195 of the total number. Of the authors of 20 or more species, Bartoš, Marcus, Murray, and Thulin described infraspecific forms while Mihelčič and Richters did not. Examination of the descriptions of the subspecies shows most of them resulted from single collections, often at the same locality as the nominate species. One may question the validity of such subspecific classification in the light of modern systematic concepts.

There exists a considerable body of literature dealing with the extremes of environment endured by the anabiotic forms of tardigrades. Pigon and Weglarska (1955) have determined metabolic rates of these resistant forms and Rahm (1937),

Le Gros (1955), and Mathews (1938) list a number of diverse ecological situations where tardigrades have been found. We have not, however, seen a single paper delimiting the precise conditions under which a species goes about living normally. These requirements appear to be quite broad and, along with the ability of the tardigrades to survive adverse conditions temporarily, they must have allowed many species to become cosmopolitan in distribution. Thus most species uncovered by our collections were usually found to be species well known in Europe. Although nearly one-third of the known species occur in North America, few are recorded only from this region.

MATERIALS AND METHODS

Tardigrada collected in the states of Alaska, Arizona, California, Idaho, Oregon, Nevada, and Washington were considered in this study. Emphasis was placed on the Tardigrada of California, collections from the other states being few and capricious. Even the California collections were largely fortuitous. However, in excess of 3,000 slides were prepared, representing 161 localities in California (see the distribution map) and 58 additional localities outside of California. As multiple samples often were collected at a single locality, the number of samples containing tardigrades was in excess of 350. The infrequency with which newly-found species were encountered toward the end of the study indicated that the tardigrade fauna had been rather adequately sampled.

Habitat samples, mainly of lichens and mosses, were brought to Davis by co-operating individuals. These samples were placed in wire-mesh containers (8-mesh) shaped to fit into quart-sized funnels, the bottoms of which had been stoppered. The samples were soaked for one to four hours and then removed. The water was decanted except for that remaining in the neck of the funnel. This small remaining amount of water, with the tardigrades, was then poured into petri dishes for examination under a dissecting microscope. Dirty samples were cleaned using a Fenwick funnel with 100- and 200-mesh screens. Extraction of very small transparent specimens from the samples by employing a flow of hot water was found to be quite useful when living material was not desired. This treatment rapidly separated the tardigrades from the plant material and the opaque white color resulting from coagulated protein made them easier to see.

The plant samples are now part of the cryptogam collection of the Department of Botany at Davis. Scientific names of the plants are to be assigned to the respective lots, but some of this information is not now available.

Considering the large number of tardigrades present in most samples, the slide preparation of only a few individuals of each species seemed to be practical. The resulting collection, therefore, does not reflect the relative abundance of species in any one sample.

The tardigrades usually were mounted singly in iodine-tinted Hoyer's and the preparation ringed after drying. Slide labels of a thickness greater than that of the finished preparation were used so that the slides could be stacked. This procedure reduced the space requirements and storage costs of the collection.

Most of the world literature was acquired and bound, and is deposited with the tardigrade collection at Davis.

Representatives of the more common species have been placed in the collections



Map 1. Distribution of California collections.

of the California Academy of Sciences; Department of Zoology, University of California, Berkeley; California State Department of Agriculture; American Museum of Natural History; and the collection of Franz Mihelčič in Austria. The remaining material is deposited with the Department of Entomology, University of California, Davis.

ACKNOWLEDGMENTS

We are indebted to many people whose names appear below as collectors. It was through the assistance of these individuals, collecting mosses and lichens while pursuing other interests, that this study was possible. The cooperation of Dr. J. M. Tucker, curator of the botany herbarium, and that of Dr. F. C. Raney in securing plant identifications is appreciated. Dr. F. Mihelčič and Dr. G. Ramazzotti very kindly identified or confirmed identification of examples of most of

the tardigrade species. The cost of expendable items and of some literature was defrayed by a Faculty Research Grant.

Individual collectors are identified in collection records by their initials. They are R. P. Allen, S. F. Bailey, A. J. Beck, J. S. Buckett, J. C. Campbell, D. Q. Cavagnaro, W. A. Cordoza, T. L. Fenner, K. Goeden, A. A. Grigarick, L. L. Grigarick, F. D. Horn, Y. Hokama, W. G. Iltis, M. E. Irwin, W. H. Lange, C. D. MacNeill, D. and G. Mansfield-Jones, D. L. Mays, H. W. Michalk, C. G. Moore, D. Parker, F. D. Parker, F. C. Raney, W. G. Roberts, V. D. Roth, E. I. Schlinger, R. O. Schuster, R. P. Schuster, L. Stange, D. A. Taylor, V. L. Vesterby, R. F. Wilkey, and R. K. Washino.

LOCALITY AND ECOLOGICAL DATA

To avoid the needless repetition of collection data, this information is listed once here. The distribution of individual species will be summarized later and specifically referred to these data by number.

ALASKA

Popof Island

0. Sand Point

Bog surface, mid-June, 1963 (WGR)

ARIZONA

Cochise County

1. Barfoot Mtn., Chiricahua Mtns., 8,700 ft.

Lichen on rock, VII-10-63 (JSB)

2. Onion Saddle, 7 miles NW Southwest Research Station, 7,400 ft.

A. Lichen on dead *Pseudotsuga menziesii*, XI-12-62 (VDR)

B. Lichen, VII-10-63 (JSB)

C. Moss, XI-12-62 (VDR)

3. Rustler Park Road, Chiricahua Mtns., 6,400 ft.

Lichen on bark of log, VII-14-56 (D & GM-J)

Maricopa County

4. Roosevelt Dam

Moss, XII-5-62 (AAG)

Santa Cruz County

5. Roundup Recreation Area, Madera Canyon, 5,700 ft.

A. Lichen on rock, VIII-28-63 (VLV)

B. Moss on rock, VIII-28-63 (VLV)

C. Lichen on *Quercus* bark, VIII-28-63 (VLV)

D. Lichen, VIII-28-63 (VLV)

6. Santa Rita Lodge, Madera Canyon, 5,000 ft.

A. Liverworts, VIII-29-63 (VLV)

B. Club moss on soil, VIII-29-63 (VLV)

C. Moss on soil, VIII-29-63 (VLV)

CALIFORNIA

Alameda County

7. Berkeley

A. Moss, on *Calocedrus* IX-4-62 (FCR)

B. Moss, II-25-63 (ROS)

8. Oakland

A. Moss, VI-23-62 (ROS)

B. Lichen on *Crataegus*, VI-23-62 (ROS)

C. Moss on soil, III-24-63 (ROS)

9. Oakland, in hills on Ascot Drive
Moss near stream, VI-23-62 (ROS)

Alpine County

10. Woodsfords, 2 mi. S
Lichen on rock, VII-28-63 (AAG)

Amador County

11. Ione, 5 mi. SE
Lichen on *Arctostaphylos myrtifolius*, V-5-62 (FCR)

Butte County

12. Biggs Rice Experiment Station
A. Lichen on *Populus fremontii*, XI-9-62 (AAG)
B. Lichen on moss on *Ulmus*, XI-9-62 (AAG)
C. Algae in rice field, VII-24-63 (RKW)
13. Fall River
Lichen, VI-16-63 (FCR)
14. Richvale, 3 mi. SW
Aquatic, *Myriophyllum spicatum*, III-1-63 (FCR)

Colusa County

15. Colusa County line, on Highway 16
A. Lichen on rocks, I-20-63 (ROS)
B. Lichen on twigs, I-20-63 (ROS)
16. Williams
Lichen on trunk of *Ailanthus*, VI-14-62 (FCR)

Contra Costa County

17. Lafayette
Moss on soil surface, XII-26-62 (CGM)
18. Russelman Park at Trail Ride, Mt. Diablo
A. Lichen on greasewood twigs, XII-27-62 (CGM)
B. Moss and lichen on rock, XII-27-62 (CGM)
C. Lichen on trunk of *Quercus*, XII-27-62 (CGM)
D. Rotting leaves of *Quercus* sp. and *Photinia californica*, XII-27-62 (CGM)

Del Norte County

19. Patrick Creek
A. Moss, VI-28-63 (SFB)
B. Lichen, VI-28-63 (SFB)

El Dorado County

20. Bridalveil Picnic Area on Highway 50, near Riverton
A. Moss on falls, III-21-63 (ROS)
B. Lichen on moss on bark and twigs, III-21-63 (ROS)
C. Moss on rock, III-21-63 (ROS)
21. Camp Sacramento, 6,500 ft.
A. Lichen on bark, I-25-63 (CGM)
B. Moss and lichen on rocks, I-25-63 (CGM)
22. Pacific House
Lichen on *Quercus* branch, IV-30-62 (AAG)
23. Shingle Springs, 7 mi. NE
Lichen on *Quercus* branch, II-12-63 (RFW)
24. Glenn Alpine
Lichen, VII-5-62 (FCR)

Fresno County

25. Fresno, 26 mi. E, on Highway 180, 1,000 ft.
Lichen on *Quercus*, X-31-62 (AAG)
26. Fresno, 43 mi. E on Highway 180, 3,800 ft.
A. Lichen and moss on trees, X-31-62 (AAG)
B. Lichen and moss on granite rock, X-31-62 (AAG)
C. Moss on soil surface, X-31-62 (AAG)

27. Fresno, 46 mi. E on Highway 180, 4,300 ft.
A. Lichen and moss on *Pinus*, X-31-62 (AAG)
B. Lichen and moss on *Quercus*, X-31-62 (AAG)
28. General Grant Grove, Kings Canyon National Park
A. Moss on *Sequoia* log, X-31-62 (AAG)
B. *Letharia* on *Abies* trunk, X-31-63 (AAG)
29. Golden Trout Lake, Humphreys Basin
Moss on soil, VII-26-63 (AAG)
30. Kelso Valley, 11.7 mi. NW, 5,800 ft.
Lichen on *P. jeffreyi* (FCR)
31. Monterey County line, 7 mi. E
Lichen on *Quercus*, II-21-63 (DAT)
32. Pinehurst, 6 mi. N, on Highway 180, 5,200 ft.
Gyrophora on granite, III-20-63 (AAG)
- Glenn County*
33. Butte City, 3 mi. E
Lichen on *Salix*, II-12-63 (AAG)
- Humboldt County*
34. Scotia, .5 mi. S
A. Moss on bark of *Sequoia*, I-26-63 (JCC)
B. Lichen on *Sequoia*, I-26-63 (JCC)
- Inyo County*
35. Camp Sabrina
Moss and lichen on rock, VII-28-63 (AAG)
36. North Lake
Moss on soil, VII-28-63 (AAG)
37. Piute Pass, 11,423 ft.
Lichen and moss on soil under rock, VII-27-63 (AAG)
- Kern County*
38. Kelso Valley, 10.4 mi. NW
A. Lichen on *Quercus*, III-7-63 (FCR)
B. Lichen on rocks, III-7-63 (FCR)
- Lake County*
39. Cobb Mtn.
Moss, III-13-62 (JSB-MEI)
40. Kelsey Creek, Cobb Mtn.
III-13-62 (JSB-MEI)
- Lassen County*
41. Hallelujah Junction
Lichen on soil, XII-28-62 (MEI-FDP)
- Madera County*
42. Pinedale, 4 mi. N on Highway 41
Lichen and moss on *Salix*, XI-21-63 (AAG)
43. Selma, 25 mi. N, 100 ft.
Ficus branches, III-20-62 (FCR)
- Marin County*
44. Alpine Dam, 1.5 mi. E
A. Lichen on rock, I-23-63 (DQC-MEI)
B. Aquatic plants, mainly *Lemna*, IV-14-63 (DQC)
C. Lichen and moss on bank of road-cut, I-23-63 (DQC-MEI)
45. Alpine Dam, 2 mi. E
A. Moss on *Aesculus* trunk, I-23-63 (DQC-MEI)
B. Lichen and moss on *Quercus*, I-23-63 (DQC-MEI)
46. Black Point
A. Moss on bark, V-3-63 (YH)
B. Moss, V-3-63 (YH)

47. Dillon Beach
 - A. Alga on barnacles, II-6-63 (AAG-ROS)
 - B. Lichen and moss on rocks, II-6-63 (FCR)
48. Dillon Beach, 1.4 mi. E
Lichen and moss on *Lupinus arboreus*, II-6-63 (FCR)
49. Fairfax, 10 mi. W
Lichen and moss in litter of *Quercus* and *Sequoia*, VII-23-62 (LS)
50. Fort Barry
Moss in swamp, IV-10-63 (RKW)
51. Marshall, 8 mi. E
 - A. Moss, XI-12-62 (JSB)
 - B. Lichen, XI-12-62 (JSB)
52. Mt. Tamalpais
Lichen, on *Quercus agrifolia*, VII-23-62 (LS)
53. Point Reyes, near
Lichen, XI-10-62 (AJB)
54. Samuel P. Taylor State Park
Lichen and moss mixed, XI-18-62 (JSB)
55. Tomales, 2.9 mi. E
 - A. Lichen on rock, II-6-63 (FCR-ROS)
 - B. Lichen and moss on franciscan sandstone, II-6-63 (FCR-ROS)
56. Woodacre
Moss, XI-22-62 (AJB)

Mariposa County

57. Groveland Ranger Station, 8.5 mi. E-SW
Lichen and moss on *Quercus kelloggii*, IX-22-62 (FCR)

Mendocino County

58. Bald Mtn.
Lichen, VII-21-62 (AAG)
59. Mendocino, 1 mi. from ocean
XII-26-62 (WGI)
60. Post Camp, Etsel Ridge
Moss, VII-22-62 (AAG)

Merced County

61. Stevinson, 2 mi. S
Lichen on twigs, VI-20-63 (AAG)

Modoc County

62. Lava Camp, 20 mi. NW Lookout
Lichen, X-13-62 (WAC)

Mono County

63. Barcroft Station, White Mtn., 11,500 ft.
Eriogonum, V-1-62 (AAG)
64. Crooked Creek Research Station, White Mtn., 10,150 ft.
 - A. Moss under *Pinus aristata*, V-1-62 (AAG)
 - B. Moss, V-1-62 (AAG)
65. Dry Creek, 1.5 mi. E Mono Mills
Moss and lichens, VIII-8-63 (AJB)

Monterey County

66. Arroyo Seco
 - A. Lichen on rock, II-22-63 (MEI)
 - B. Club moss, II-22-63 (MEI)
67. Bradley, 3 mi. N, 540 ft.
Lichen on trunk and twigs of *Quercus douglasii*, IX-28-62 (FCR)
68. Castroville, 4 mi. W
Lichen on *Quercus* twigs, II-12-63 (HWM)

69. Priest Valley
Lichen and moss on *Quercus*, II-21-63 (DAT)
70. Salinas, 10 mi. W
Nephroma on *Quercus agrifolia*, XI-13-62 (JSB)

Napa County

71. Angwin, Pacific Union College
IV-29-62 (SFB)
72. Bale Mill
Moss on *Aesculus*, V-22-62 (SFB)
73. Capell Creek, near Berryessa Reservoir
Lichen on *Quercus*, VII-27-63 (ROS)
74. Glass Mtn. Ranch, 10 mi. N St. Helena, on Silverado Trail
Litter, under *Acer macrophyllum*, V-6-62 (FCR)
75. Los Pasados State Park
A. Lichen on bark dead *Pinus sabiniana*, IX-6-62 (AJB)
B. Lichen, VIII-15-62 (AJB)
C. Moss, VIII-15-62 (AJB)
76. Mt. St. Helena
Rotting *Pseudotsuga menziesii* cone, III-13-62 (JSB-MEI)
77. Oakville
Quercus lobata, IV-26-62 (SFB)
78. Rutherford
Lichen on *Quercus dumosa*, XI-4-62 (MEI)
79. Rutherford, 3 mi. E
A. Moss on *Umbellularia californica*, XI-4-62 (MEI)
B. Lichen on twigs on soil surface, XI-4-62 (MEI)
80. Wooden Valley
Litter of *Quercus* and *Vitis californica*, IV-29-62 (SFB)

Nevada County

81. Martis Creek, 2 mi. S Truckee
Moss, XI-22-62 (FDP-MEI)

Orange County

82. Santiago Canyon (Fleming Ranch), Santa Ana Mtns.
A. Lichen on dead *Quercus*, VIII-18-62 (MEI)
B. Moss on rock under *Alnus rhombifolia*, VIII-18-62 (MEI)
C. Lichen on bark of *Quercus agrifolia*, VIII-18-62 (MEI)

Placer County

83. Colfax, SE
Aquatic plants, IV-30-63 (RKW)
84. Eucure Bar, 6 mi. SE Baxter, North Fork American River
Moss on rock, X-31-62 (TLF)

Plumas County

85. Beckwourth Mtn., 4 mi. SE Portola, 7,000 ft.
A. *Letharia* and moss on rock, XI-3-62 (AAG)
B. Moss on soil surface, XI-3-62 (AAG)
86. Bottle Springs, 11 mi. SW Quincy
Moss, VI-9-63 (AAG)
87. Graeagle, 7 mi. W
Lichen, VIII-5-63 (WAC)
88. Grizzley Dome, 6 mi. N Mayaro
Moss, VI-9-63 (AAG)
89. McCarthy Bar, Middle Fork Feather River, 10 mi. S Quincy
A. Moss, VI-9-63 (AAG)
B. Lichen, VI-9-63 (AAG)
90. Quincy, 12 mi. S, 4,000 ft.
Lichen on *Calocedrus*, VI-17-62 (AAG)

91. Rock Creek, 6 mi. W Quincy
Moss on rock, VI-29-62 (RKW)
- Riverside County*
92. Banning, 6 mi. S, 4,000 ft.
Lichen on *Quercus agrifolia*, III-6-63 (FCR)
93. Coyote Creek, near Deep Canyon (no precipitation for 8 years), 900 ft.
Moss under rock, II-6-63 (EIS)
94. Hemet, 20 mi. S, Summit Round Top, 3,500 ft.
Lichen on *Simmondsia*, IX-23-62 (FCR)
95. Idyllwild, 5 mi. S, 4,200 ft.
Lichen on *Quercus*, III-6-63 (FCR)
96. San Jacinto, 12 mi. NW, 1,650 ft.
Lichen on granite rock, III-6-63 (FCR)
97. Tualata Creek, 5 mi. W Sage
Lichen, VII-3-63 (EIS)
- Sacramento County*
98. Perkins, 14 mi. E
A. Lichen on rock, III-21-63 (ROS)
B. Lichen and moss on soil, III-21-63 (ROS)
- San Benito County*
99. Gilroy, 13 mi. S
A. Moss and lichen, IX-28-62 (FCR)
B. Lichen on soil surface, IX-28-62 (FCR)
100. Hollister, 20 mi. S
A. Lichen on *Quercus* branch, III-21-63 (DAT)
B. Lichen on *Quercus*, III-21-63 (DAT)
- San Francisco County*
101. Golden Gate Park, San Francisco
Moss on New Zealand tree fern, I-18-63 (CDM)
- San Joaquin County*
102. Lodi
A. Lichen on *Vitis vinifera*, IV-18-62 (ROS)
B. Lichen on *Vitis vinifera* var. *Tokay*, IX-22-62 (FCR)
- San Luis Obispo County*
103. Atascadero, 3.8 mi. N
Lichen on branch of *Quercus kelloggii*, IX-28-62 (FCR)
- San Mateo County*
104. Memorial Park, 6 mi. W Pescadero
A. Lichen on bark, VIII-20-63 (AAG)
B. Moss on rocky soil, VIII-20-63 (AAG)
C. Lichen, VIII-20-63 (AAG)
105. Waterdog Lake, Belmont
Lichen, III-11-62 (ROS)
- Santa Clara County*
106. Los Gatos
A. Moss, XII-16-62 (JCC)
B. Lichen on *Quercus*, XII-16-62 (JCC)
- Santa Cruz County*
107. Henry Cowell Redwoods State Park
A. Moss, VIII-21-63 (AAG)
B. Lichen on bark, VIII-21-63 (AAG)
C. Lichen, VIII-21-63 (AAG)
- Shasta County*
108. Anderson
A. 2 mi. NW, IV-21-63 (AAG)
B. 3 mi. NW, lichen, IV-21-63 (AAG)

143. Two Rock Ranch, 9 mi. W Petaluma
Lichen on roof shingles, II-6-63 (FCR)
Stanislaus County
144. La Grange, 2 mi. SW, 200 ft.
Lichen on *Quercus* branch, XII-31-62 (RPS)
145. Oakdale
Lichen on bark and twigs of *Quercus*, IX-22-62 (FCR)
Sutter County
146. Robbins, 7 mi N
Moss on *Salix*, XI-9-62 (AAG)
Tehama County
147. Proberta
Lichen and moss on trunk of *Juglans*, XII-28-62 (AAG)
Trinity County
148. Hayfork, 8 mi. E, 3,660 ft.
A. Lichen on *Quercus*, V-21-62 (RFW)
B. Lichen on *Pseudotsuga menziesii*, V-21-63 (TRH)
C. Lichen on *Pinus*, V-21-63 (RFW)
D. Moss on rock, V-21-63 (RFW)
149. Lewiston
Lichen and moss on *Quercus*, XII-26-62 (AAG)
150. Trinity Dam
A. Moss on soil surface, XII-26-62 (AAG)
B. Lichen and moss on *Abies*, XII-26-62 (AAG)
151. Weaverville, 2 mi. SE, 2,041 ft.
A. Lichen on *Pinus*, XII-26-62 (AAG)
B. Moss on rocks, XII-26-62 (AAG)
Tulare County
152. Auckland, 3.1 mi. NE, 1,600 ft.
A. Lichen on redwood fence post, III-20-63 (FCR)
B. Lichen on *Aesculus californica*, III-20-63 (FCR)
153. California Hot Springs, 5.2 mi. N, 4,000 ft.
On granite, III-20-63 (FCR)
154. Fresno, 51 mi. E, 5,700 ft.
A. *Letharia* on *Calocedrus*, X-31-62 (AAG)
B. *Letharia* on *Pinus*, X-31-62 (AAG)
C. Lichen and moss on granite rocks, X-31-62 (AAG)
155. Johnsondale, 6 mi. N-NW, 6,000 ft.
Lichen on *Calocedrus decurrens*, III-7-63 (FCR)
Tuolumne County
156. Crane Flat Ranger Station, 7,000 ft.
Lichen on *Abies magnifica*, IX-22-62 (FCR)
157. Groveland, 1 mi. N, 3,500 ft.
Lichen and moss on *Quercus kelloggii*, IX-22-62 (FCR)
158. Hardins Flat, 1.5 mi. W-NW
Lichen and moss on *Calocedrus*, IX-22-62 (FCR)
159. Pioneer Trails Camp Ground, near Dodge Ridge, 6,000 ft.
Lichen, VI-17-63 (TLF)
160. Tuolumne Meadows, 12 mi. W, 8,600 ft.
Lichen on *Pinus jeffreyi*, IX-22-62 (FCR)
161. Yosemite National Park, 2.6 mi. inside boundary, 7,000 ft.
Lichen on *Abies magnifica*, IX-22-62 (FCR)
Ventura County
162. Ventura, 30 mi. E
Lichen on *Quercus agrifolia*, IX-27-62 (FCR)

Yolo County

163. Davis, 40 ft.
A. Lichen on rock, VI-29-62 (AAG)
B. Lichen on rock, XI-4-62 (ROS)
C. Lichen on *Ulmus* bark, VI-5-63 (WGI)
D. Lichen, VIII-7-63 (ROS)
E. Lichen on *Acacia*, III-6-62 (ROS)
F. Alga on *Quercus suber*, XII-19-62 (ROS)
G. Moss, III-2-62 (ROS)
164. Durst Ranch, 400 ft.
Lichen on *Photinia*, XII-19-62 (CGM)
165. Rumsey, 2.5 mi. N
A. Lichen on rocks, I-20-63 (ROS)
B. Moss, seepage on sandstone, I-20-63 (ROS)
166. Rumsey, 3 to 4 mi. N
A. Lichen on rocks, I-20-63 (ROS)
B. Moss on sandstone wall, I-20-63 (ROS)
C. Lichen on *Quercus* twigs, I-20-63 (ROS)
D. Moss on rocks, I-20-63 (ROS)
167. Winters, 5 mi. S
Lichen on *Quercus*, VI-16-62 (ROS)
168. Marysville, 10 mi. S (Sunset Pump)
Lichen on *Juglans hindsii*, VIII-13-62 (FCR)

IDAHO

Kootenai County

169. Tubbs Hill, 1 mi. E Coeur d'Alene
Lichen, VI-29-62 (FCR)

NEVADA

Elko County

170. Mountain City, 25 mi. SW, in Independence Range
Moss, IX-8-62 (AAG)

Washoe County

171. Fort Sage, 40 mi. N Reno
A. Moss on rocks, XI-24-62 (MEI-FDP)
B. Lichen on dead *Juniperus*, XI-24-62 (MEI-FDP)
172. Reno Hot Springs
Moss on soil surface, XII-27-62 (MEI-FDP)

OREGON

Benton County

173. Corvallis
A. Lichen on *Robinia*, VI-15-62 (FCR)
B. Lichen on *Plantanus orientalis*, VII-30-62 (FCR)
C. Lichen on *Ulmus americanus*, VIII-30-62 (FCR)
D. Lichen on *Acer*, VII-30-62 (FCR)

Clackamas County

174. Government Camp, Mt. Hood
Lichen, VI-29-63 (WHL)
175. Rhododendron
Moss, VI-27-63 (WHL)

Clatsop County

176. Arch Cape
Sticta and moss, VI-16-62 (FCR)

Columbia County

177. Goble
Moss, VI-27-63 (WHL)

Crook County

178. Weberg Ranch, 5 mi. S Suplee, 4,860 ft.
Lichen on fence post, IX-6-62 (KG)

Deschutes County

179. Bend
Gyrophora on basalt wall, XII-22-62 (FCR)

Douglas County

180. Camas Valley, 4 mi. E, 1,500 ft.
Lichen and moss on *Pseudotsuga menziesii*, IX-21-62 (KG)
181. Canyonville, 2 mi. S
Lichen, VI-15-62 (FCR)

Harney County

182. Burns, 25 mi. NW on road between Burns and Izee
Lichen on rock, IX-7-62 (KG)

Hood River County

183. State Highway 35, 20 mi. N US 26
Lichen on bark, XI-3-62 (DLM)

Jackson County

184. Ashland, 20 mi. S on Highway 99
A. Lichen on *Quercus*, IV-8-63 (FDH)
B. Lichen on granite, IV-8-63 (FDH)
C. Moss on granite, IV-8-63 (FDH)
185. Medford
Moss on tree, IV-8-63 (FDH)
186. Medford, 31 mi. S
Moss, IV-14-63 (FCR)

Josephine County

187. Grants Pass, 27 mi. N
Sticta and moss on *Pseudotsuga* stump, VI-14-62 (FCR,
188. Rice Hill
Lichen and moss, VI-15-62 (FCR)
189. Rice Hill, 42 mi. N
A. Lichen and moss, VI-15-62 (FCR)
B. Lichen on *Quercus*, VI-15-62 (FCR)

Klamath County

190. Crater Lake
Lichen on *Pinus albicaulis*, VIII-31-62 (FCR)

Lane County

191. Eugene, 24 mi. S, on shore of Dexter Reservoir
Lichen on stump of *Pseudotsuga menziesii*, VIII-30-62 (FCR)
192. Oakridge, 7 mi. S, near Salt Creek
Moss on log, VIII-31-62 (FCR)
193. Salt Creek Falls
Lichen on *Tsuga heterophylla*, VIII-31-62 (FCR)

Lincoln County

194. Burnt Woods, 25 mi. W Corvallis
Lichen on *Pseudotsuga* log, X-17-62 (KG)
195. Newport, 1 mi. S on Highway 101
Lichen on *Pinus contorta*, X-17-62 (KG)
196. Siletz, 3 mi. N
Lichen, VI-16-62 (FCR)

Marion County

197. Breitenbush Hot Springs, 6 mi. S-SW, 14 mi. N Detroit, 3,200 ft.
 A. Lichen on *Pseudotsuga menziesii*, X-18-62 (KG)
 B. Lichen on cedar, X-18-62 (KG)
198. Breitenbush Hot Springs, near, 14 mi. N Detroit, 2,500 ft.
 A. Lichen on *Acer macrophyllum*, X-18-62 (KG)
 B. Lichen on rock, X-18-62 (KG)
 C. Moss near base of *Acer macrophyllum*, X-18-62 (KG)

Multnomah County

199. Lewis and Clark State Park, Broughton Bluff, Troutdale
 VI-28-62 (WHL)
200. Troutdale
 Lichen and moss, VI-23-63 (WHL)

Polk County

201. Valsetz
 Moss and lichen at base of *Acer macrophyllum*, VI-16-62 (FCR)

Sherman County

202. Briggs Junction, US 30 and 97
 Moss on basalt, XII-30-62 (FCR)

Tillamook County

203. Neskowin, 4 mi. S
 Moss on *Tsuga heterophylla*, VI-16-62 (FCR)

Union County

204. Starkey, 15 mi. SW La Grande
 A. Lichen and moss on rock, XI-14-62 (KG)
 B. Lichen on *Pinus ponderosa* log, IX-14-62 (KG)

Washington County

205. North Plains, 4 mi. NW
 Lichen on *Pyrus*, VIII-14-62 (KG)

WASHINGTON

Whitman County

206. Pullman
 Lichen on *Robinia pseudoacacia*, VI-22-62 (FCR)

King County

207. Winslow, Bremerton Island, 75 ft.
 Moss on *Pseudotsuga menziesii*, VI-19-62 (FCR)

Pierce County

208. Buckley, 2 mi. E
 Moss on *Pseudotsuga* stump, VI-20-62 (FCR)
209. Chinook Pass, 36 mi. E Buckley, 6,500 ft.
 A. Lichen, VI-20-62 (FCR)
 B. Lichen and moss, VI-20-62 (FCR)

Spokane County

210. China Pond
 Lichen on *Pinus ponderosa*, VI-25-62 (FCR)
211. Glentana Fish Hatchery, 2 mi. NW Spokane
 A. Moss on *Pseudotsuga menziesii*, VI-29-62 (FCR)
 B. Lichen on *Pinus ponderosa*, VI-29-62 (FCR)
212. Lincoln Park, Spokane
 Moss on *Acer*, VI-25-62 (FCR)
213. Meade
 A. 12 miles SE, lichen, VI-27-62 (FCR)
 B. 13 mi. SE, lichen, VI-27-62 (FCR)
 C. 2 mi. SW, *Amelarchia*, VI-27-62 (FCR)

- 214. Meade, 15 mi. NE
Usnea on *Abies grandis*, VI-27-62 (FCR)
- 215. Mt. Spokane, 17 mi. NE Meade
 - A. Lichen, VI-27-62 (FCR)
 - B. *Fontinalis* along streambank, VI-27-62 (FCR)
- 216. Mt. Spokane State Park, 1.9 mi. from top
 Lichen, VI-27-62 (FCR)
- 217. Mt. Spokane
 Lichen on *Larix* bark, VI-27-62 (FCR)
- 218. Spokane, 2,200 ft.
 - A. Moss on granite outcrop, XII-26-62 (FCR)
 - B. Lichen on *Malus malus*, XII-28-62 (FCR)
 - C. Lichen on *Acer*, VI-24-62 (FCR)
 - D. Lichen and moss, XII-23-62 (FCR)
- 219. Wandermere Park, 8 mi. N Spokane
 - A. Lichen on *Pseudotsuga* bark, XII-29-62 (FCR)
 - B. Moss on soil surface, XII-29-62 (FCR)
 - C. Lichen and moss on granite, XII-29-62 (FCR)
 - D. Lichen on *Pseudotsuga* log, XII-29-62 (FCR)

DISTRIBUTION

Reports on the occurrence of Tardigrada in North America north of Mexico are assembled in table 1. The names of species not previously recorded within this geographical area are marked by asterisks. Authorities for the records on distribution are identified by numbers in parentheses.

SYSTEMATICS

The mouthparts (fig. 1) are taxonomically very important and the component structures are identified as follows. In the Heterotardigrada the stylets are not attached to the buccal tube although they may lie parallel to the tube as far as the pharynx. The pharynx contains thin sclerotized placoids which are not detached from the buccal tube. The muscular pharynx becomes cleared in Hoyer's medium and is not shown on any illustrations in this paper. In the Eutardigrada and in the Mesotardigrada the placoids are more or less distinctly separated from each other and from the buccal tube and are often thickened. Anteriorly there is a buccal ring which may or may not have definable peripheral papillae. Behind this is a stylet sheath. The stylets are hinged at the furca and are connected to the buccal tube by stylet supports. The tube anterior to the stylet supports is called the buccal tube, and that part between the stylet supports and the pharynx is termed the pharyngeal tube. The mouth tube of *Macrobiotus* usually has an apodeme ventrally, called the buccal tube support. The pharyngeal tube normally ends with an obvious thickening, the apophysis. Two or three macroplacoids are numbered consecutively from anterior to posterior. Microplacoids may or may not occur behind the last macroplacoid and if a single fused structure is present it is called the septulum. The shape of the pharynx and the distribution of the placoids within it are frequently helpful in species determination. It is advisable, therefore, to note the pharynx as well as any irregularities of the cuticle before the specimens become completely cleared.

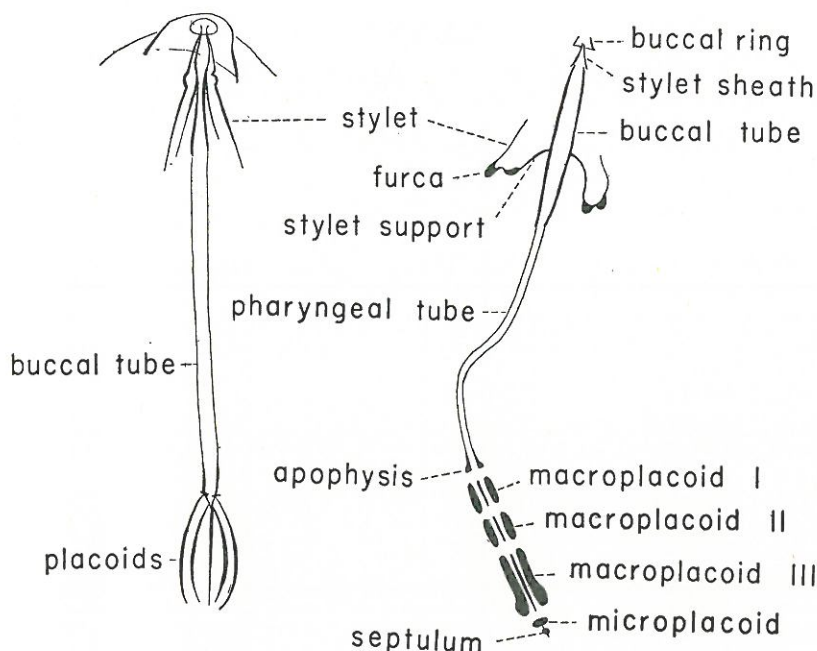


Fig. 1. Mouthparts of Heterotardigrada (left) without stylet supports and without free placoids, and of Eutardigrada (right) with free placoids as they appear when mounted in Hoyer's.

KEY TO ORDERS OF TARDIGRADA¹

- 1 Head with lateral cirrus (spine) on each side..... 2
- Head without lateral cirriEutardigrada
- 2(1) Pharynx with placoids separate from mouth tubeMesotardigrada
- Pharynx without separate placoidsHeterotardigrada

KEY TO FAMILIES OF THE ORDER EUTARDIGRADA

- Mouth opening not surrounded by obvious papillae; pharynx with placoids (except *Itaquascon*) claws each with two similar branches from a common base, or unbranched (*Macrobotus*, *Haplomacrobotus*, *Hypsibius*, and *Itaquascon*)Macrobotidae
- Mouth opening surrounded by six obvious papillae; pharynx without placoids; principal and secondary branches of claws separated (monogeneric, *Milnesium*).....Milnesiidae

The order Mesotardigrada contains one family, Thermozodiidae, with one monotypic genus, *Thermozodium*.

KEY TO SUBORDERS OF HETEROTARDIGRADA

- Median cirrus present (except *Halechiniscus gutteli*)Arthrotardigrada
- Median cirrus absentEchiniscoidea

KEY TO FAMILIES OF THE SUBORDER ARTHROTARDIGRADA

- 1 Legs not ending in digits, claws immediately inserted
(monogeneric: *Stygartus*)Stygartidae
- Legs ending in digits 2

¹ The keys to supraspecific categories are essentially as prepared by Ramazzotti, with departures resulting chiefly from loose translation.

Species	Ala.	Ariz.	Calif.	Idaho	Nev.	Ore.	Wash.	B. C.	Other N. Amer. areas
<i>Batillipes friaufi</i>	(8)
<i>Batillipes mirus</i>	(4)
<i>Batillipes pennaki</i>	(4)
<i>Bathychiniscus tetronyx</i> (in error).....	(2)	..	..	..	..	..	..
<i>Echiniscoides sigismundi</i>	x	..	..	..	..	..	(7)
<i>Echiniscus</i> (<i>E.</i>) <i>arctomys</i>	x	..	..	..	..	..	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>blumi</i>	x	x	..	x	x	..	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>bisetosus</i>	(6)	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>canadensis</i>	x(5)	..	..	..	..	(6)	..
<i>Echiniscus</i> (<i>H.</i>) <i>gladiator</i>	x	..	x	..	..	x	..	(6)	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>granulatus</i> (? in error)....	(8)
<i>Echiniscus</i> (<i>B.</i>) <i>intermedius</i>	(6)	(1)
<i>Echiniscus</i> (<i>E.</i>) <i>mauccii</i>	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>merokensis</i>	(5)	..	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>multipinosus*</i>	x	..	..	x	..	..	..
<i>Echiniscus</i> (<i>E.</i>) <i>oihonnae</i>	x	..	..	..	..	(6)	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>phocae</i> (in error).....	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>quadriscopiosus*</i>	x	..	..	..	..	..	..
<i>Echiniscus</i> (<i>B.</i>) <i>parvulus</i>	(5)	..
<i>Echiniscus</i> (<i>E.</i>) <i>reymondi</i>	(5)	..
<i>Echiniscus</i> (<i>E.</i>) <i>robertsi*</i>	x	..	..	..	..	..	..	..	..
<i>Echiniscus</i> (<i>E.</i>) <i>sylvanus</i>	(6)
<i>Echiniscus</i> (<i>E.</i>) <i>testudo*</i>	x	..	x	..	..	..	..
<i>Echiniscus</i> (<i>E.</i>) <i>trisetosus*</i>	x	..	..	x	..	..	..
<i>Echiniscus</i> (<i>E.</i>) <i>virginicus</i>	(8)
<i>Echiniscus</i> (<i>E.</i>) <i>wendti</i>	x	..	..	..	..	..	(8)
<i>Haplomacrobiotus hermosillensis*</i>	x	..	..	..	..	..	..
<i>Hypsibius</i> (<i>C.</i>) <i>ornatus*</i>	x	..	..	..	..	..	..	..	..
<i>Hypsibius</i> (<i>D.</i>) <i>alpinus</i>	x	..	..	..	x	..	x	..	(6)
<i>Hypsibius</i> (<i>D.</i>) <i>angustatus</i>	x	..	..	x	x	..	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>belgicae</i>	x	..	..	..	..	..	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>bullatum</i>	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>chilenensis</i>	(6)
<i>Hypsibius</i> (<i>D.</i>) <i>nodosus</i>	x	..	..	..	..	..	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>oculatus</i>	x	..	..	x	x	(7)	..
<i>Hypsibius</i> (<i>D.</i>) <i>pinguis</i>	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>illisii.*</i>	x	..	..	..	..	..	..
<i>Hypsibius</i> (<i>D.</i>) <i>scoticus</i>	x	..	..	x	x	(6)	(8)
<i>Hypsibius</i> (<i>D.</i>) <i>spitzbergensis*</i>	x	..	..	..	..	..	..
<i>Hypsibius</i> (<i>D.</i>) <i>stappersi</i>	(8)
<i>Hypsibius</i> (<i>H.</i>) <i>arcicus</i>	(6)	..
<i>Hypsibius</i> (<i>H.</i>) <i>calcaratus*</i>	x	..	..	x	..	..	..
<i>Hypsibius</i> (<i>H.</i>) <i>conjungens</i>	(8)
<i>Hypsibius</i> (<i>H.</i>) <i>convergens</i>	x	..	..	x	x	..	(8)
<i>Hypsibius</i> (<i>H.</i>) <i>dujardini</i>	(8)
<i>Hypsibius</i> (<i>H.</i>) <i>oberhaeuseri</i>	x	x	..	x	x	x	(6)	(5)
<i>Hypsibius</i>									

Species	Ala.	Ariz.	Calif.	Idaho	Nev.	Ore.	Wash.	B. C.	Other N. Amer. areas
<i>Hypsibius (I.) augusti</i>	x	...	...	...	...	...	(4)
<i>Hypsibius (I.) canadensis</i>	(5)	...	...	...	...	(6)	(8)
<i>Hypsibius (I.) granulifer</i>	(8)
<i>Hypsibius (I.) nodosus</i>	(8)
<i>Hypsibius (I.) prosostomus</i>	x	...	...	...	...	...	(8)
<i>Hypsibius (I.) sattleri</i>	x	...	...	x	...	...	(6)
<i>Hypsibius (I.) tetradactyloides</i>	(8)
<i>Hypsibius (I.) schaudinni</i>	(8)
<i>Hypsibius (I.) ?tuberculatus</i>	x	...	...	...	...	(6)	(8)
<i>Itaquascon umbellinae</i>	(8)
<i>Macrobiotus areolatus</i>	x	x	...	...	x	x	(6)	...
<i>Macrobiotus echinogenitus</i>	(6)	(8)
<i>Macrobiotus furcatus</i>	(7)
<i>Macrobiotus harmsworthi</i>	x	x	...	...	x	x	...	(8)
<i>Macrobiotus hufelandii</i>	x	x	x	x	...	x	x	(6)	(8)
<i>Macrobiotus intermedius</i>	(8)
<i>Macrobiotus islandicus</i>	x	x	x	...	...	x	x	...	(8)
<i>Macrobiotus macronyx</i>	x	...	...	...	...	...	(8)
<i>Macrobiotus ovovillosus</i>	(1)
<i>Macrobiotus richtersi</i>	x	x	...	x	...	...	(8)
<i>Macrobiotus tonollii</i>	(8)
<i>Macrobiotus occidentalis</i>	(6)	...
<i>Macrobiotus virgatus</i>	(6)	...
<i>Milnesium tardigradum</i>	x	x	x	x	x	x	...	(8)
<i>Pseudechiniscus goedeni</i>	x(3)	...	...	...
<i>Pseudechiniscus novaezeelandiae</i>	(7)
<i>Pseudechiniscus ramazzottii</i>	(8)
<i>Pseudechiniscus raneyi</i>	x(3)	...	...	x	...	...	...
<i>Pseudechiniscus suillus</i>	x(5)	...	...	...	...	...	(8)
<i>Pseudechiniscus victor</i>	x(3)	...	...	x	...	...	...
<i>Styraconyx sargassi</i>	x(7)	...	...	...	...	...	...

Authorities:

1. Baumann, 1960
2. Chitwood, 1954
3. Grigarick et al., 1964

4. Higgins, 1959
5. Mathews, 1938
6. Murray, 1910

7. Ramazzotti, 1962
8. Riggins, 1962
- x This study

- 2(1) Legs with four digits, each terminating in a claw (*Halechiniscus*, *Pleocola*, *Actinarctus*, *Tetracentron*, *Styraconyx*, *Tanarctus*, and *Bathyechiniscus*).....Halechiniscidae
- Legs with four to six digits, each distally expanded to form an adhesive disc (*Batillipes* and *Orzeliscus*)Batillipedidae

KEY TO FAMILIES OF THE SUBORDER ECHINSCOIDEA

- Dorsal cuticle not comprised of plates: claws lack spurs (*Oreella*, *Echiniscoides*, and *Archechiniscus*) Oreellidae
- Dorsum consisting of well defined plates; claws have spurs (*Echiniscus*, *Parechiniscus*, *Pseudechiniscus*, and *Mopsechiniscus*)Echiniscidae

Only seven of the 23 genera are represented in this study. We are optimistic in our belief that other genera will be found. This optimism seems fully justified

1	Lateral cirrus A present at posteriolateral margin of plate A (head plate).....	2
	Lateral cirrus A absent	20
2(1)	Pharynx with placoids separate from mouth tube	<i>Thermozodion</i>
	Pharynx without distinct placoids separate from mouth tube.....	3
3(2)	Median cirrus present—i.e., with odd number of cirri; exclusively marine.....	4
	Median cirrus absent—i.e., with even number of cirri.....	12
4(3)	Body enveloped in gelatinous membrane.....	<i>Actinarctus</i>
	Body not enveloped in gelatinous membrane	5
5(4)	Distal extremities of legs not digitate, terminating in claws; dorsal plates present	<i>Stygarrctus</i>
	Extremities of legs digitate; dorsal plates absent.....	6
6(5)	Digits terminating in adhesive discs or in peg-shaped structures.....	7
	Digits terminating in claws	8
7(6)	Six unequal digits distally expanded.....	<i>Batillipes</i>
	Four digits with peg-shaped terminations of almost equal shape.....	<i>Orzeliscus</i>
8(6)	Claws with spurs	9
	Claws without spurs	11
9(8)	Body flattened	<i>Tetrakenton</i>
	Body not flattened	10
10(9)	Median cirrus short	<i>Styraconyx</i>
	Median cirrus long	<i>Bathyechiniscus</i>
11(8)	Clava much shorter than lateral cirrus, length at most 6μ	<i>Pleocola</i>
	Clava greatly developed, at least 15μ long, often as long as lateral cirrus.. <i>Halechiniscus</i>	
12(3)	Claws distally on distinct digits	13
	Claws directly on legs, legs not digitate	15
13(12)	Two internal claws on digits, two external claws directly on leg.....	<i>Archechiniscus</i>
	All claws on digits	14
14(13)	Lateral cirrus A very long (100μ), subequal to length of animal; caudal extremity of body bifurcate, consisting of two large, conical lobes with terminal filament 220μ long	<i>Tanarctus</i>
	Lateral cirrus A shorter (maximum of 40μ); caudal extremity of body not bifurcate; long caudal filaments absent	<i>Halechiniscus</i>
15(12)	Body without dorsal plates	16
	Body, at least partially, with plates	17
16(15)	Legs with four claws	<i>Oreella</i>
	Legs with five to eleven claws; exclusively marine.....	<i>Echiniscoides</i>
17(15)	Dorsal plates delimited only in posterior region.....	<i>Parechiniscus</i>
	Entire dorsum covered by well defined plates.....	18
18(17)	Terminal plate E directly behind plates D, or with only intersegmental (median) plate interposed	<i>Echiniscus</i>
	Terminal plate E separated from plates D by transverse plate or plate pair (pseudo-segmental plate)	19

- 19(18) Buccal cirri absent *Mopsechiniscus*
 Buccal cirri present *Pseudechiniscus*
 20(1) Six rostral papillae surround mouth opening..... *Milnesium*
 Mouth opening not surrounded by rostral papillae..... 21
 21(20) Legs terminating in two unbranched claws..... *Haplomacrobotus*
 Legs terminating in two claws, each with primary and secondary claw..... 22
 22(21) Claws of each leg equal in size and shape..... *Macrobotus*
 Claws of each leg unequal in size, asymmetrical..... 23
 23(22) Pharynx always without placoids *Itaquascon*
 Pharynx with placoids except during molts..... *Hypsibius*

Macrobotidae Thulin, 1928

Haplomacrobotus May, 1948

This monospecific genus is easily recognized because each leg possesses two single claws instead of the normal double claw.

Haplomacrobotus hermosillensis May, 1948

(Fig. 2)

This large species may reach 550μ in length. Eye spots are present and the cuticle is smooth and brownish in color. Each leg ends in two thin, curved, unbranched

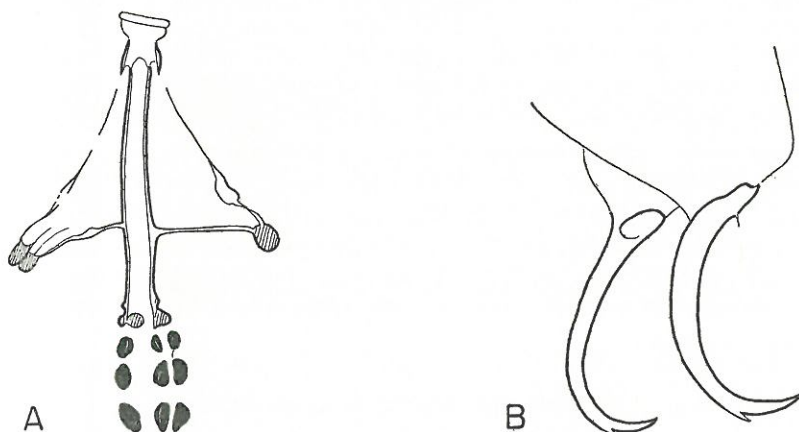


Fig. 2. *Haplomacrobotus hermosillensis*: A. Mouthparts. B. Claws of leg IV.

claws. The pharynx contains three macroplacoids of which the first is the smallest and the third the largest.

H. hermosillensis was originally described from Mexico. Specimens from southern California, sample 93, appear to be conspecific and thus extend the distribution northward into the United States.

Macrobotus Schultze, 1834

Macrobotus is distinguished from the related genus *Hypsibius* by the structure of its claws. The double claws of each leg are equal in size and each an image of the other.

The buccal tube of *Macrobotus* usually has a single longitudinal apodeme on its ventral face. Members of this genus deposit their eggs individually except in rare cases where they are deposited in groups in the cast cuticle. The individually deposited eggs have a characteristic ornamentation, and this is useful or even essential for species determination.

KEY TO *MACROBIOTUS*

- 1 Three separate macroplacoids present 2
 - Two macroplacoids present, or if questionably three, first two contiguous..... 4
- 2(1) Microplacoid present 3
 - Microplacoid absent *M. areolatus*
- 3(2) Length of pharyngeal section subequal to width of buccal tube..... *M. richtersi*
 - Pharyngeal section longer than width of buccal tube..... *M. harmsworthi*
- 4(1) Principal and secondary branches of claws united for nearly one-half their length; not aquatic 5
 - Principal and secondary branches of claws strongly diverge from base; aquatic *M. ?macronyx*
- 5(4) First macroplacoid much longer than second; microplacoid present..... *M. hufelandii*
 - First macroplacoid but slightly longer than second; microplacoid absent.... *M. islandicus*

Macrobotus areolatus Murray, 1907

(Figs. 3, 4)

A moderate to large species with a reported length of 800 μ . The majority of individuals examined were about 475 and the largest 740 μ . The cuticle is smooth and colorless, and eye spots may or may not be present. The pharynx is oval and the placoids occupy approximately the anterior three-fourths of it.

A cosmopolitan species frequent in our collections, *M. areolatus* has been taken in Arizona, California, Oregon, and Washington, in these localities: 2C; 3; 5A; 6A, B; 7; 9; 17; 18B; 19A, B; 32; 39; 40; 44A, C; 45A, B; 46A, B; 47B; 48; 51A, B; 53; 54; 55A; 70; 72; 77; 79A; 85A; 97; 99; 105; 109; 119; 126B; 136; 138D; 140C; 141; 142A, B, C; 148A, D; 153; 163G; 166A, D; 173; 175; 179; 192; 198A; 200; 205; 211A.

Macrobotus richtersi Murray, 1911

(Fig. 4)

This is a large species, some individuals attaining a length of about 1,000 μ . The cuticle is smooth, usually white, but may be brownish in color. The buccal tube is very wide, often over 15 μ in large individuals, and the pharyngeal section is very short. The pharynx contains 3 macroplacoids, of which the third is the longest, and a microplacoid. We have not collected eggs with the adults, but have based the determination solely on the buccal apparatus.

This species is reported from Africa, Europe, Greenland, North America, and South America. Specimens have been collected in California, Idaho, and Oregon at the following localities: 8C; 9; 72; 80; 101, 107A; 163A, G; 169; and 185. All but one of the specimens were from very damp moss.

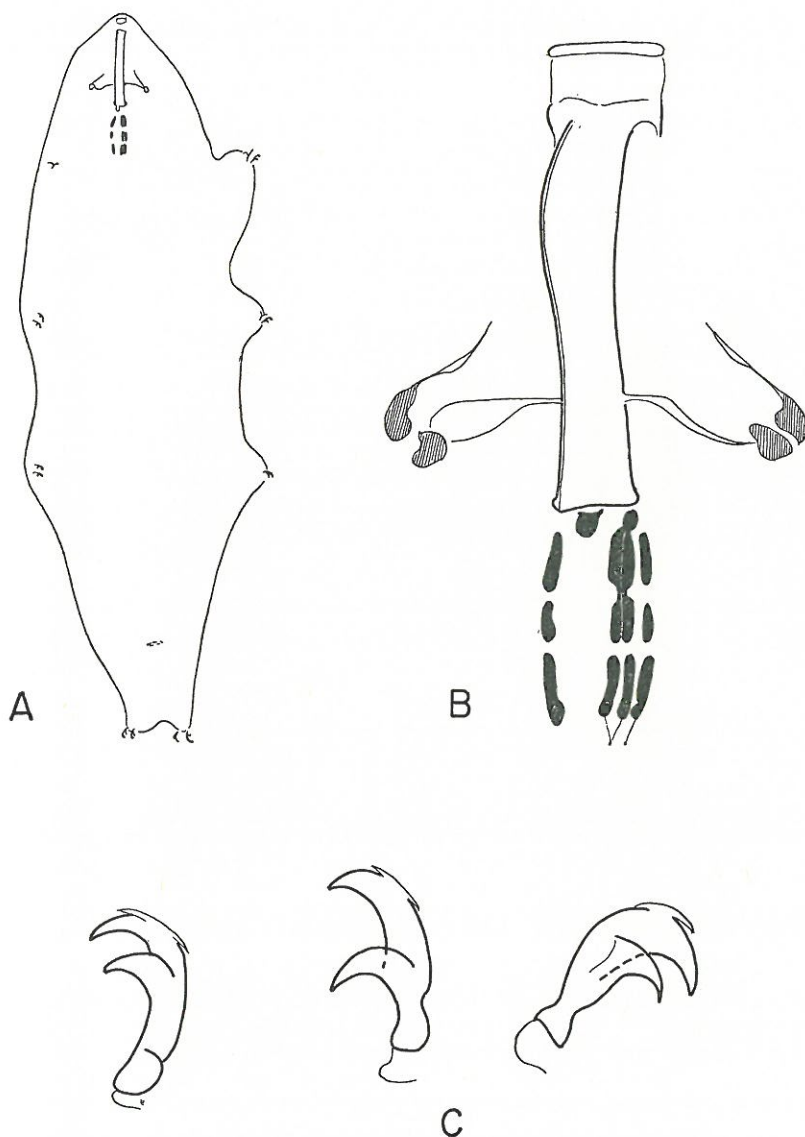


Fig. 3. *Macrobotus areolatus*: A. Dorsal view. B. Mouthparts. C. Claws.

Macrobotus harmsworthi Murray, 1907

(Fig. 5)

The length of this species may exceed 700μ , but usually it is smaller. The cuticle is smooth and eye spots often are present. The mouth tube is rather wide, and the placoids occupy about four-fifths of the elongate pharynx. Three macroplacoids, of which the third is slightly larger, and microplacoids are present.

M. harmsworthi is cosmopolitan. Identification is based partly on the ornamentation of the egg that is deposited individually. Eggs with basally sculptured

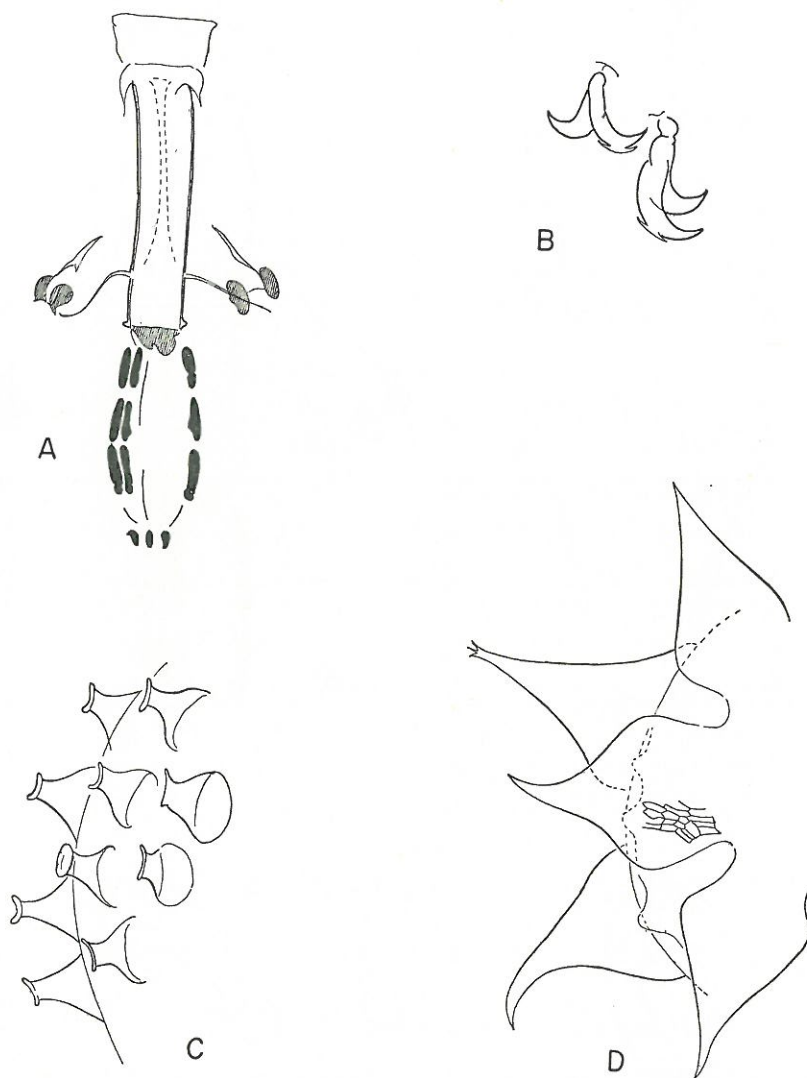


Fig. 4. *Macrobiotus richtersi*: A. Mouthparts. B. Claws of leg IV. *Macrobiotus hufelandii*: C. Ornamentation of egg. *Macrobiotus areolatus*: D. Ornamentation of egg.

processes were attributed to the subspecies *M. harmsworthi coronatus* by Barros (1942). Since eggs were infrequently found and their sculpturing difficult to assess, we have not attempted to distinguish between subspecies.

This species was collected in Arizona, California, Oregon, and Washington. Approximately 350 specimens from the following localities were examined: 0; 2A; 3; 5; 10; 11; 13; 20A, C; 21A; 27A; 28A, B; 29; 31; 33; 34B; 35; 37; 44C; 45A; 48; 51B; 60; 66A, B; 74; 75A, B, C; 73; 78; 82A; 85A, B; 87; 89A, B; 95; 99A; 100B; 103; 105; 109A, C, D; 113D; 125C; 130; 131A; 133A, B; 135; 138D; 139B;

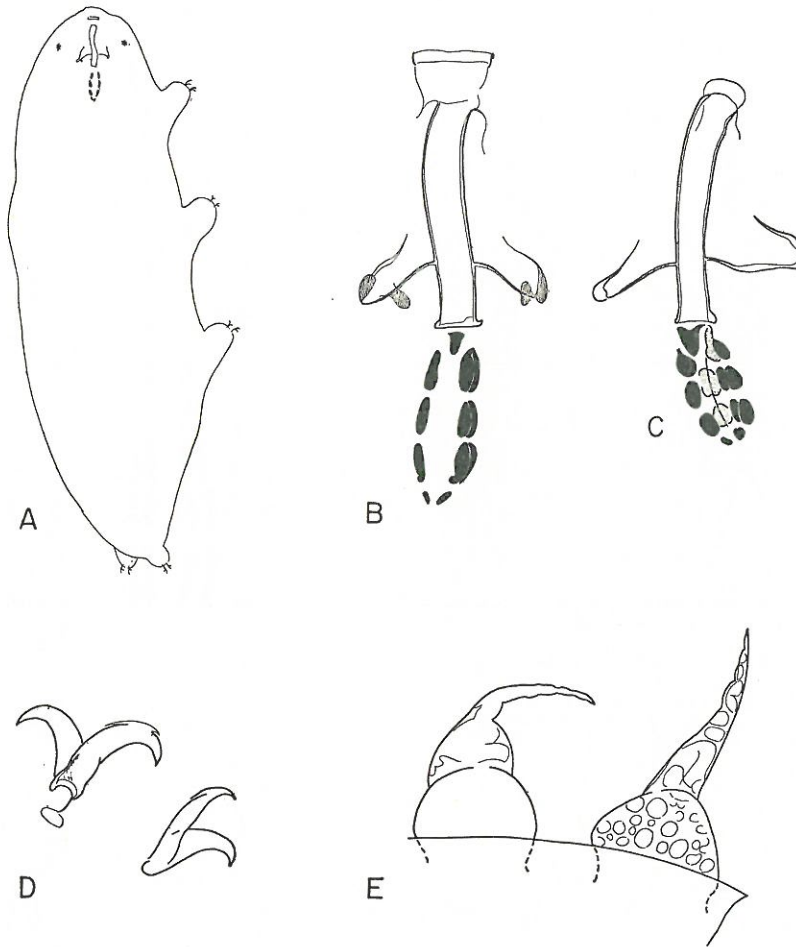


Fig. 5. *Macrobiotus harmsworthi*: A. Dorsal view. B. Adult mouthparts. C. First instar mouthparts. D. Claws of leg IV. E. Processes of egg.

140B; 141; 142B, C; 146; 147; 148C; 154B, C; 155; 158; 160; 161; 168; 179; 183; 185; 187; 190; 196; 197A, B; 207; 208; 211A; 214; 217; 219A, B, and C.

Macrobiotus?macronyx Dujardin, 1851

(Fig. 6)

Three species of *Macrobiotus*—*M. ambiguus*, *M. dispar*, and *M. macronyx*—are presumably indistinguishable on the basis of adult characters. The eggs are reported by various authors to differ somewhat in the spacing of the processes or in the lack of them. Unfortunately, the eggs found in our collections could not be associated with particular adults. The egg of *M. ambiguus* has the processes contiguous at their bases. That of *M. dispar* has the processes arising at a distance from each other. *M. macronyx* deposits eggs in its old cuticle and they are smooth. We have elected to use the name *macronyx* as applied to a species already recorded from North America.

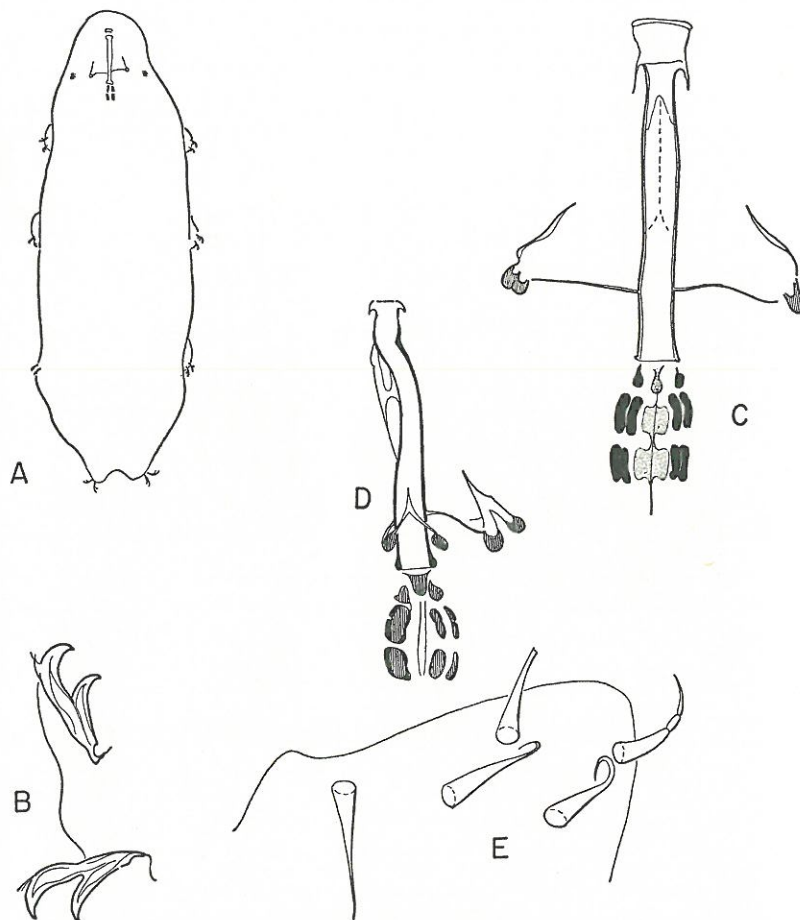


Fig. 8. *Macrobiotus islandicus*: A. Dorsal view. B. Claws of leg IV. C. Mouthparts of adult. D. Mouthparts of emerging individual. E. Section of egg shell with processes.

Macrobiotus islandicus Richters, 1903

(Fig. 8)

Specimens may reach 600μ in length and have a smooth or finely pitted cuticle. Some individuals may be yellow in color. Eye spots are frequently present. The slightly oval pharynx contains two macroplacoids of which the first is the largest. A microplacoid is absent. The eggs are laid singly and the processes on the shell are long, thin, sometimes septate, and widely separated from each other.

M. islandicus has been reported as occurring in Europe, Greenland, Iceland, and in the United States (Colorado). The following localities represent collections in Alaska, Arizona, California, Oregon, and Washington: 0; 5A; 19; 20A, B; 26; 39; 44A; 45A, B; 53; 57; 69; 72; 73; 82B; 84; 85; 99B; 107A, B; 108B; 109A; 110A, C; 116; 131B; 133A, B; 136; 142A, B, C; 148A; 152A, B; 165; 166D; 174; 180; 188; 189; 194; 198; 200; 218A.

Hypsibius is a large genus divided into subgenera on the basis of the characters in the following key.

- | | | |
|------|---|--------------------------------------|
| 1 | Posterior claw with weakly sclerotized area separating principal and secondary branches | 2 |
| | Posterior (external) claw without weakly sclerotized (flexible) area between principal and secondary branch | subgenus <i>Calohypsibius</i> Thulin |
| 2(1) | Pharyngeal tube shorter, not flexible | 3 |
| | Pharyngeal tube flexible, always longer than one-half length of pharynx | subgenus <i>Diphascon</i> Plate |
| 3(2) | Secondary branch of external claw and base of claw continuously and evenly arched | subgenus <i>Hypsibius</i> Thulin |
| | Secondary branch of external claw forms a right angle with base | subgenus <i>Isohypsibius</i> Thulin |

1	Pharyngeal tube flexible, generally longer than length of bulb.....	2
	Pharyngeal tube not flexible, less than one-half length of pharynx.....	7
2(1)	Three macroplacoids and microplacoid	3
	Two macroplacoids, with or without microplacoid.....	4
3(2)	Pharyngeal tube more than twice length of placoids; placoids granular <i>H. (Diphascon) alpinus</i>	
	Pharyngeal tube less than twice length of placoids; placoids narrow rods <i>H. (D.) scoticus</i>	
4(2)	First macroplacoid longer than second	5
	First macroplacoid shorter than second	6
5(4)	Entire dorsum covered with large regular polygons..... <i>H. (D.) iltisi</i>	
	Dorsum smooth or irregularly and weakly granulate caudally..... <i>H. (D.) oculatus</i>	
	Dorsum tuberculate at least in posterior one-half; tubercules become larger caudally <i>H. (D.) nodulosus</i>	
6(4)	Pharyngeal tube thick, distinctly annulate, approximately as long as macroplacoids, microplacoid absent	<i>H. (D.) angustatus</i>
	Pharyngeal tube thick, distinctly annulate, approximately as long as macroplacoids, microplacoid present	<i>H. (D.) spitzbergensis</i>
	Pharyngeal tube thin, twice as long as macroplacoids.....	<i>H. (D.) belgicæ</i>
7(1)	Dorsum not covered with rows of flexible spines; posterior double claw with principal branch flexibly attached to secondary branch	8
	Dorsum covered with rows of flexible spines; posterior double claw with principal and secondary branches rigidly joined	<i>H. (Calohypsibius) ornatus</i>
8(7)	Three macroplacoids, or if two, first deeply constricted, appearing as two closely joined	9
	Two macroplacoids, first may have transverse suture, not deeply incised.....	10
9(8)	Macroplacoids distinctly three in number with third largest; cuticle smooth <i>H. (Isohypsibius) prosostomus</i>	
	Macroplacoids of two contiguous granules anteriorly and one larger granule posteriorly; dorsum with transverse rows of large gibbosities	<i>H. (I.) sattleri</i>
10(8)	Dorsum tuberculate or gibbose	11
	Dorsum with at most a reticulate sculpture	12
11(10)	Dorsum tuberculate, with tubercules of similar size.....	<i>H. (Hypsibius) calcaratus</i>
	Dorsum with a few large gibbosities, sculptured with irregular, interconnected polygons <i>H. (I.) ?tuberculatus</i>	
12(10)	Principal branch of double claw long, thin, not appreciably wider at base than near apex.....	13
	Principal branch of double claw appreciably wider at base.....	<i>H. (H.) convergens</i>

13(12) Principal branch of external claw long, thin, secondary branch short and stout

H. (H.) oberhaeuseri

Principal and secondary branches long, thin, subequal in size; (aquatic) *H. (I.) augusti*

Hypsibius (Diphascon) alpinus (Murray, 1906A)

(Fig. 9)

A small to moderate sized species with a maximum length of about 400 μ . The cuticle is smooth and eye spots are lacking. The pharynx contains the apophysis, three macroplacoids the size of which increases from first to third, and one microplacoid or septulum. Smooth eggs are deposited in the old cuticle.

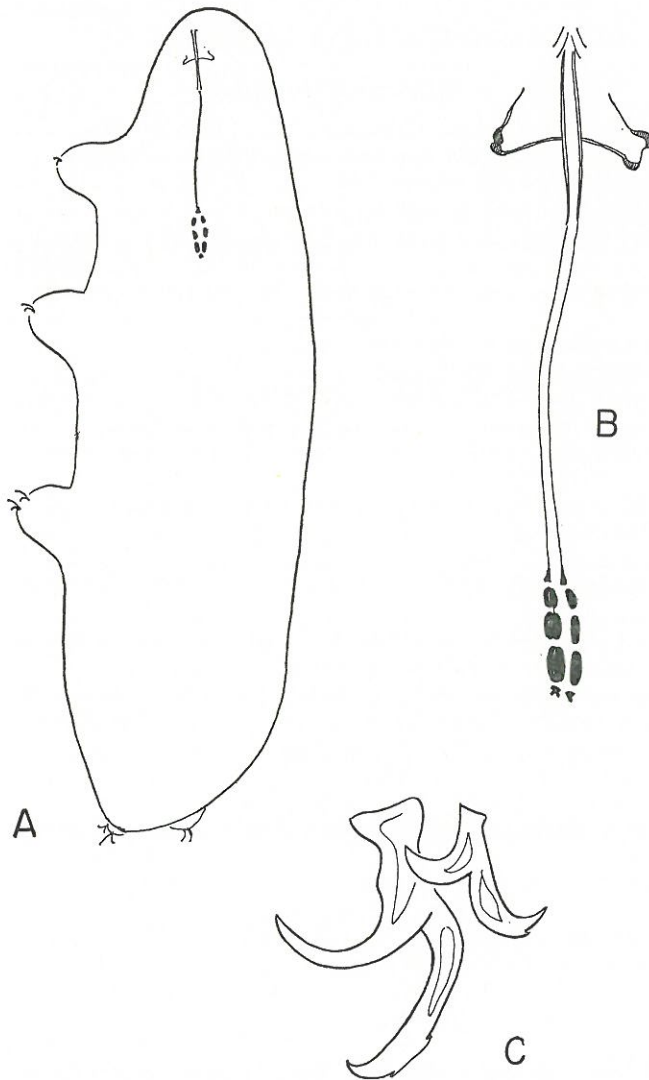


Fig. 9. *Hypsibius (D.) alpinus*: A. Dorsolateral view. B. Mouthparts. C. Claws of leg IV.

H. alpinus is a cosmopolitan species. However, it seems to be uncommon in this area, having been recovered only at localities 0, 170, and 219C, representing Alaska, Nevada, and Washington.

Hypsibius (Diphascon) scoticus (Murray, 1905)

(Fig. 10)

This species may attain a length of about 450μ . Our examples are smaller, usually 320 to 390μ . The cuticle is smooth. Three macroplacoids and the microplacoid are present with the middle macroplacoid normally the shortest. The septulum is absent.

H. scoticus has a cosmopolitan distribution, being reported from Africa, the Antarctic, Europe, Hawaii, New Zealand, North America, and South America.

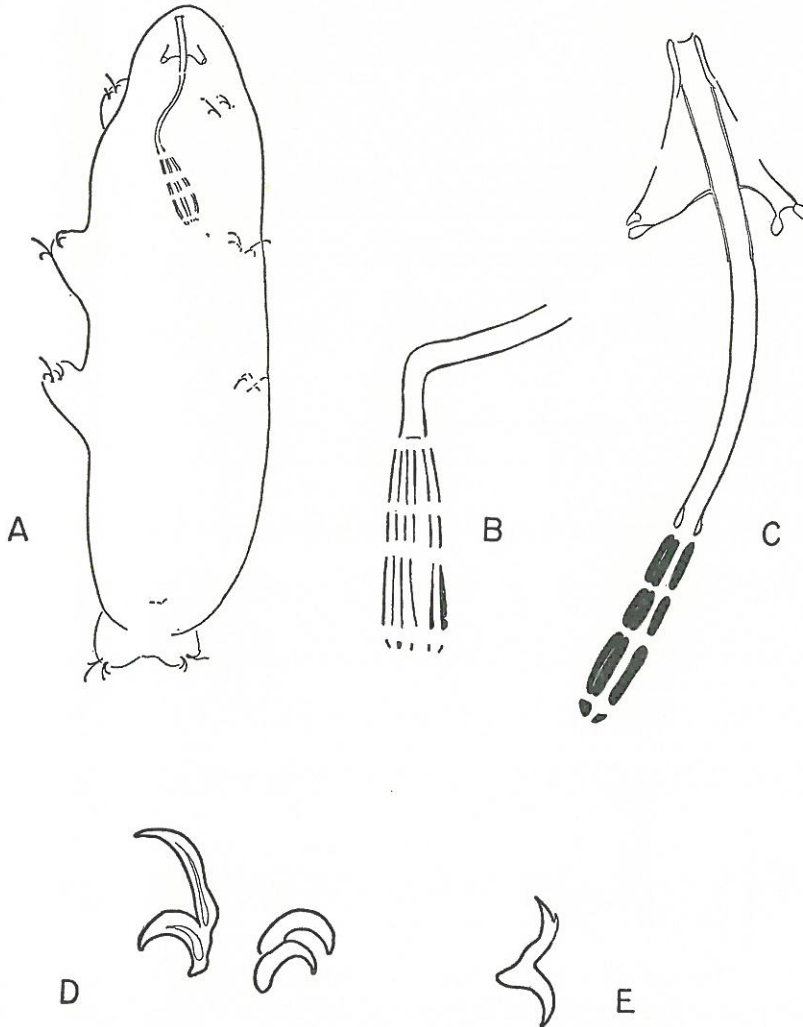


Fig. 10. *Hypsibius (D.) scoticus*: A. Dorsal view. B. and C. Mouthparts. D. and E. Claws.

We have examined specimens from eleven widely separated localities in California, Oregon, and Washington. Collections were from samples 1; 20B; 28A; 36; 83; 99B; 109A; 124A; 197A; 202; and 219B.

***Hypsibius (Diphascon) iltisi* Schuster and Grigarick, new species**

(Fig. 11)

Length 335μ . Cuticle of dorsum, including legs, with polygonal sculpture; polygons between 3μ and 4μ medianly, between 1μ and 1.5μ laterally; venter apparently smooth. Eye spots present anteriorly. Rigid section of buccal apparatus 25μ long with stylet supports attached at posterior third; flexible part of pharyngeal tube 42μ long; both buccal and pharyngeal tubes approximately 2μ in diameter.

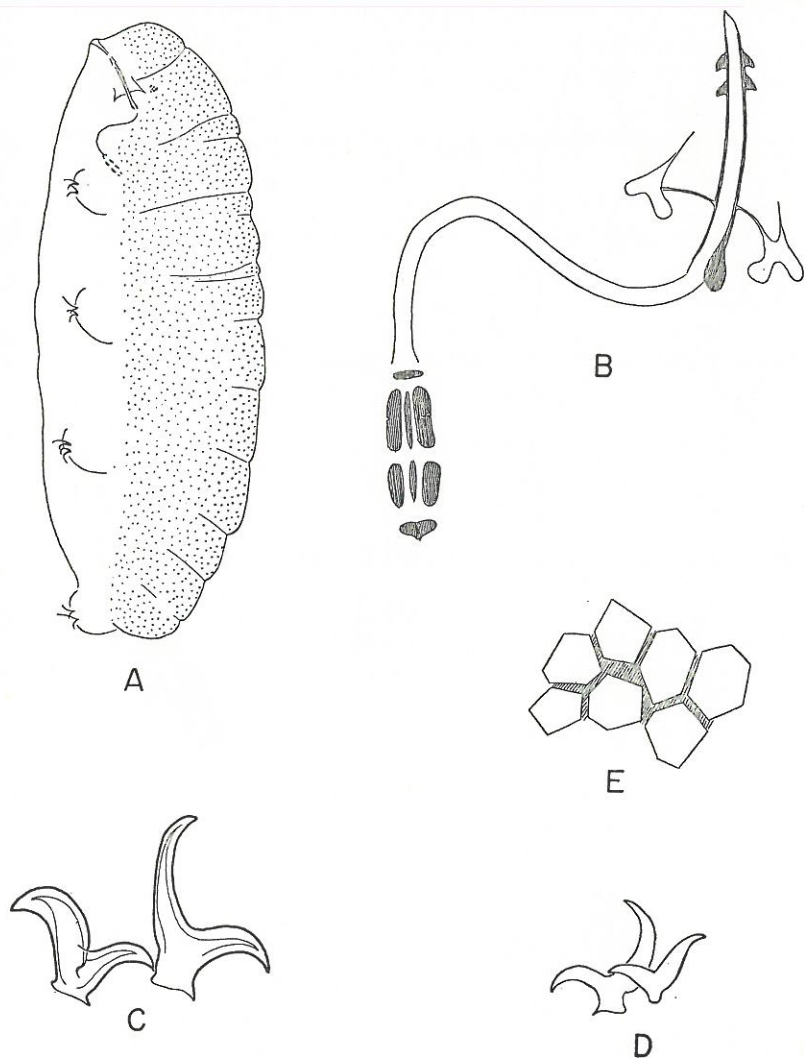


Fig. 11. *Hypsibius (D.) iltisi* n. sp.: A. Lateral view. B. Mouthparts. C. and D. Claws of leg IV. E. Pattern of cuticle.

Apophysis large; combined lengths of placoids 16μ ; macroplacoid I 7μ long, transversely divided at middle; macroplacoid II 5μ long, somewhat divided before posterior fourth; microplacoid about 3μ long.

The holotype is a fully extended specimen mounted in Hoyer's.

This species is related to *H. latipes* and to *H. rugosus*. The cuticular granulation in these species is very fine, and, in the case of *H. rugosus*, it becomes slightly larger posteriorly. *H. latipes* exhibits a smooth gibbosity on each leg. In both species the macroplacoids are rod-shaped. The cuticular granulation of *H. iltisi* is large and not increasing in size caudally, the legs lack gibbosities, and the macroplacoids are quite thick. The dorsum of two specimens is wrinkled in a somewhat regular manner suggesting, perhaps, the presence of weak gibbosities. If such gibbosities were to exist occasionally, such specimens would key to *H. (D.) nonbulatus*. In that case, the features of the placoids would be in accord, but the regular polygonal pattern of the cuticle would separate *H. iltisi* from *H. nonbulatus*, which has a scale-like derm.

From a single example it appears that seven eggs were laid in the old cuticle. These were imperfect spheres of 50μ to 60μ in diameter.

The holotype and six paratypes are deposited at Davis. The type was collected at Mt. St. Helena (sample 76) and the paratypes at California localities 59, 76, and 105.

Hypsibius (Diphascon) oculatus (Murray, 1906B)

(Fig. 12)

This species is of moderate size, measuring at most 400μ . Specimens are colorless or opaque white, and eye spots of diverse size are usually evident. The cuticle may be smooth or weakly granulate caudally. The pharyngeal tube is about twice as long as the pharynx. The latter is slightly oval and contains the apophysis, two macroplacoids, and the septulum in the anterior two-thirds. One to several eggs are deposited in the cast skin.

H. oculatus is known from Europe and North America. Nearly 200 specimens from California, Oregon, and Washington were examined from the following collections: 21A, B; 27A; 28A, B; 30; 32; 35; 37; 46; 58; 60; 62; 63; 87; 90; 110B; 112; 120B; 122; 124; 138C; 149; 151A; 154A, B; 155; 159; 160; 161; 178; 190; 204B; 209A; 213B, C; 216; and 217.

Hypsibius (Diphascon) nodulosus Ramazzotti, 1957

(Fig. 13)

Examples from California are about 25μ larger than the maximum of 260μ given by Ramazzotti. The mouthparts are similar to those of *H. oculatus*, having apophysis, two macroplacoids, and septulum. The cuticle is covered with irregularly shaped granules, much the same as for the more granular covered specimens of *oculatus*, but with the individual granules somewhat larger and tuberculate. The size of the granules obviously increases from anterior to posterior. The pattern is extended to the last pair of legs.

This species, previously known from Wisconsin, has been collected in California only twice, from lichens at localities 107B and 110B.

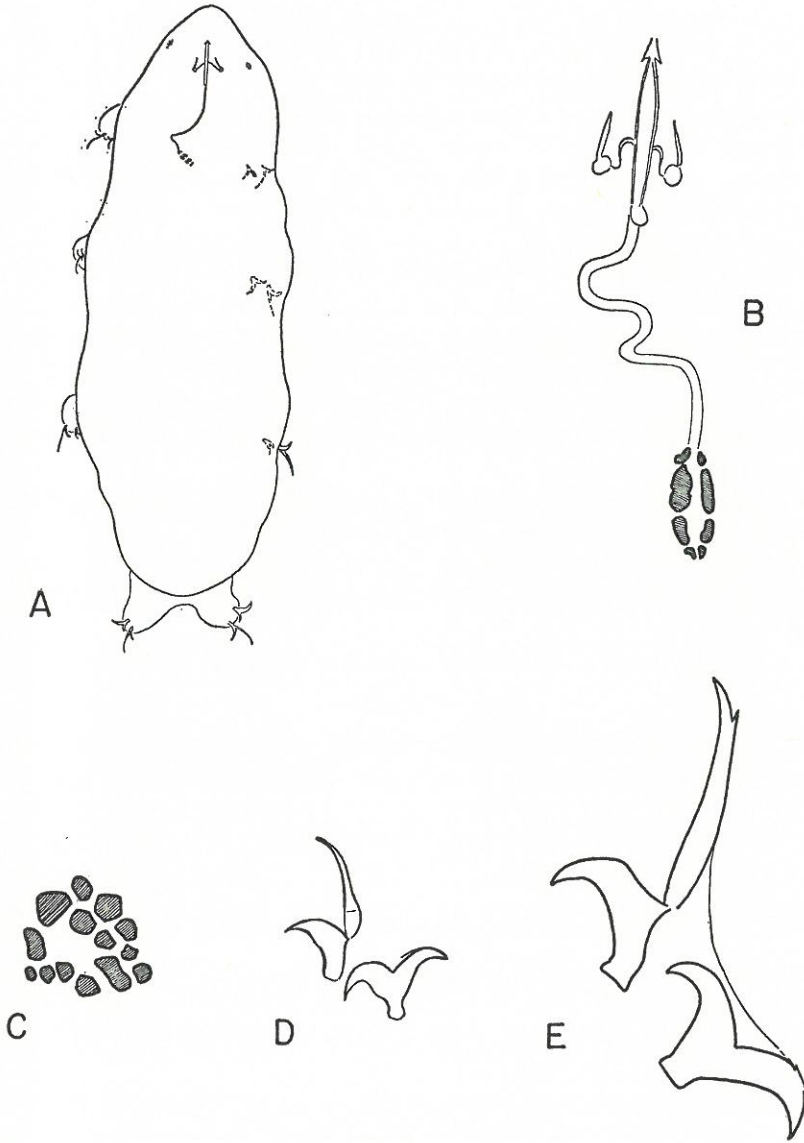


Fig. 12. *Hypsibius* (*D.*) *oculatus*: A. Dorsal view. B. Mouthparts. C. Pattern of cuticle. D. and E. Claws.

Hypsibius (*Diphascon*) *angustatus* (Murray, 1905)

(Fig. 14)

We have assigned a number of specimens to this species although their lengths of about 800μ are greater than the recorded maximum of 490μ . The mouthparts consist of a thick mouth tube with short stylet supports and appressed stylets. The pharyngeal tube is short, variable in width, but always annulate. Of the two thin macroplacoids, the second is about twice as long as the first.

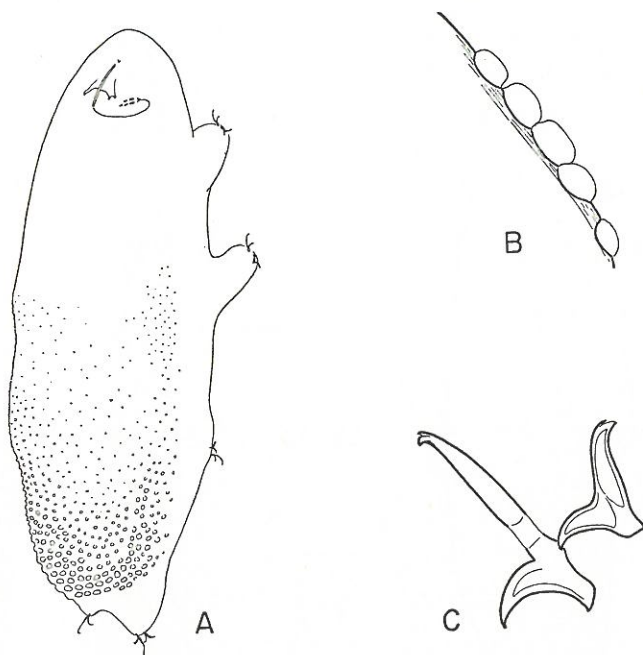


Fig. 13. *Hypsibius* (*D.*) *nodulosus*: A. Dorsal view. B. Profile of cuticle of last segment. C. Claws of leg IV.

This species is recorded from many localities in Europe and in the Arctic. We have seen specimens from the following localities: 28A; 34A; 113B; 125A; 138A; 189A; and 207. All of the samples contained moss.

Hypsibius (*Diphascon*) *belgicae* (Richters, 1911)

(Fig. 15)

H. belgicae is reported to have a length of only about 500μ , but one specimen in Hoyer's exceeds 700μ . The cuticle is smooth and eye spots are lacking. The pharyngeal tube is annulate and twice as long as the combined placoid length. Macroplacoid I is only slightly longer than one-half the length of II. A microplacoid is present. Eggs were not collected during this study and apparently they have never been described.

Reported from Spitzbergen Archipelago, and various European localities. A single specimen was recovered from moss on the soil surface at Trinity Dam, Trinity County, California, sample number 150A.

Hypsibius (*Diphascon*) *spitzbergensis* (Richters, 1903)

(Fig. 16)

A single individual measured 520μ in length. The cuticle is smooth and eye spots are apparently lacking. The length of the pharyngeal tube is subequal to the length of the placoids and is distinctly annulate. The macroplacoids are long and thin with the first one-half as long as the second. A microplacoid is present.

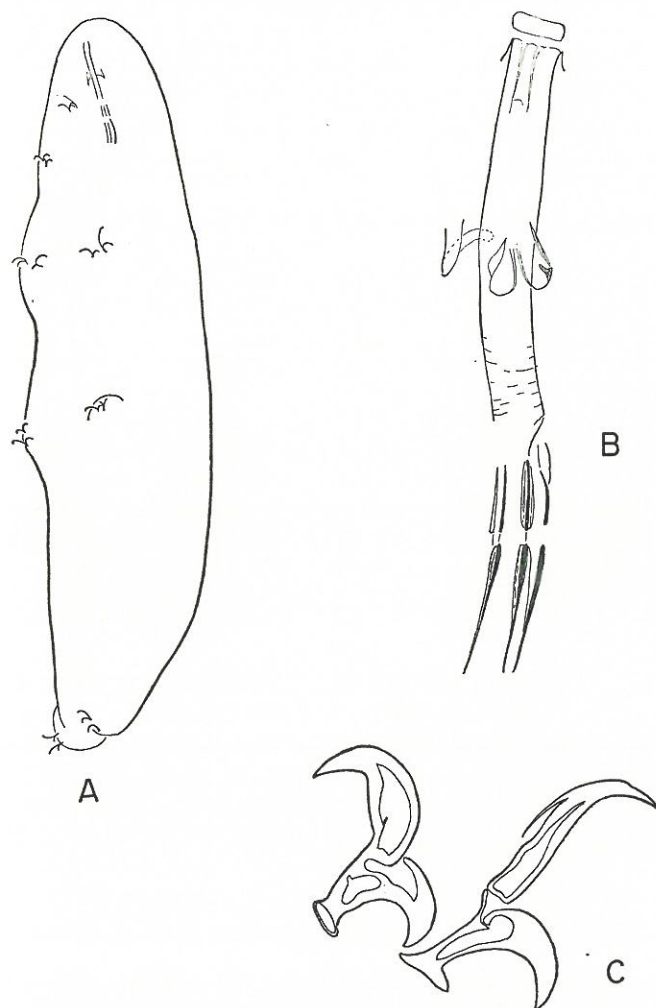


Fig. 14. *Hypsibius* (*D.*) *angustatus*: A. Dorsolateral view. B. Mouthparts. C. Claws of leg IV.

Previously recorded from various localities in Europe and the Arctic. The sole California example was taken from El Dorado County, sample number 20B.

Hypsibius (*Calohypsibius*) *ornatus* (Richters, 1900)

(Fig. 17)

This small species is less than 200μ and lacks eye spots. The dorsum is inconsistently ornamented by a combination of spines or tubercles. The mouth tube is thin and the pharynx contain an apophysis and two subequal macroploids.

H. ornatus, including over 30 varieties, is recorded from Europe, Greenland, New Zealand, and South America. We have seen one specimen from Popof Island, Alaska, sample number 0.

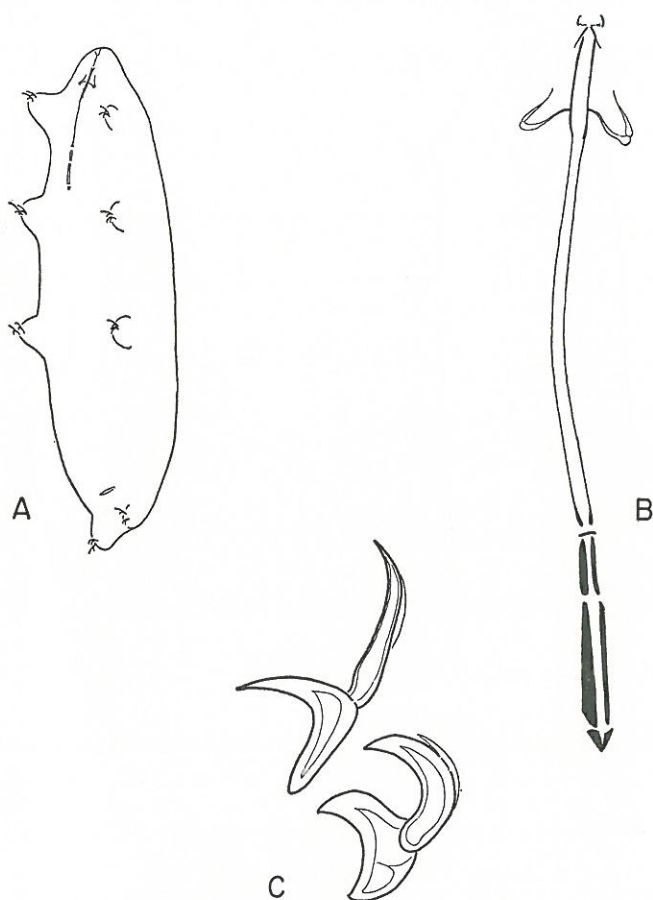


Fig. 15. *Hypsibius* (*D.*) *belgicae*: A. Dorsolateral view. B. Mouthparts. C. Claws of leg IV.

Hypsibius (*Isohypsibius*) *prosostomus* (Thulin, 1928)

(Fig. 18)

The length of *H. (I.) prosostomus* is up to 500μ . The cuticle is smooth, and eyes may be present. The pharynx contains an apophysis, three macroplacoids, and a microplacoid. The third macroplacoid is the longest. Smooth eggs are deposited in the old cuticle.

This species is listed as occurring in Europe, Indonesia, and the United States (Michigan). California localities include: 17; 21B; 44C; 50; 82; 85B; 120E; and 148A.

Hypsibius (*Isohypsibius*) *sattleri* (Richters, 1902)

(Fig. 19)

Specimens of this species were observed to be between 260μ and 280μ in length, slightly larger than recorded. They also lack eye spots, but this may be due to the

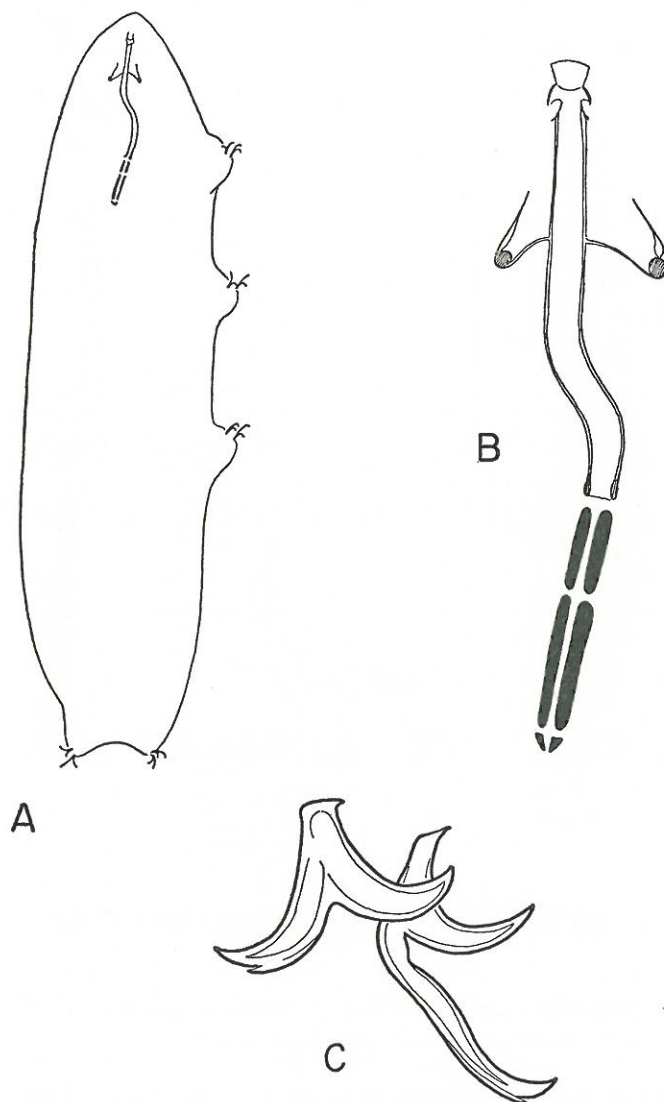


Fig. 16. *Hysibius* (D.) *spitzbergensis*: A. Dorsal view. B. Mouthparts. C. Claws of leg IV.

preparation. The dorsum has large humps, arranged in transverse rows of four, and longitudinal rows of eight. The first macroplacoid is completely divided at the middle and is longer than the second.

H. sattleri has been reported as occurring in the Arctic, Australia, Europe, New Zealand, North America, and South America. Specimens were recovered from California and Oregon localities 150A, 166B, and 174.

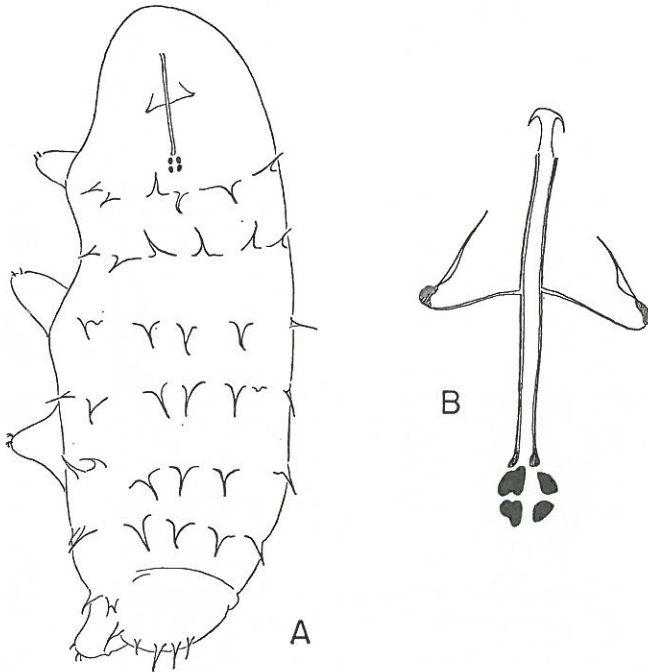


Fig. 17. *Hypsibius (C.) ornatus*: A. Dorsal view. B. Mouthparts.

Hypsibius (Hypsibius) calcaratus Bartoš, 1935

(Fig. 20)

H. calcaratus is a small species with a maximum recorded length of 200μ . A specimen of this species collected at Burnt Woods, Oregon was somewhat larger at about 250μ . The cuticle is covered with tubercles arranged in definite transverse bands. There are two macroplacoids of approximately equal size.

The California and Oregon samples 19B and 194 (both lichen) represent the first collections outside of Europe.

Hypsibius (Isohypsibius) ?tuberculatus (Plate, 1888)

(Fig. 21)

H. tuberculatus is a species of moderate size. The dorsum is semi-transparent, with faintly discernible tubercles. Tubercles also appear on some of the leg plates, at least on the fourth pair of legs. Larger transversely placed gibbosities may be present on one or more segments. The disposition of these gibbosities is useful for separating closely related species. In the few examples we have seen, the larger gibbosities do not occur on all individuals and, if present, their placement is obscure. The cuticle is sculptured with interconnected polygons of irregular size.

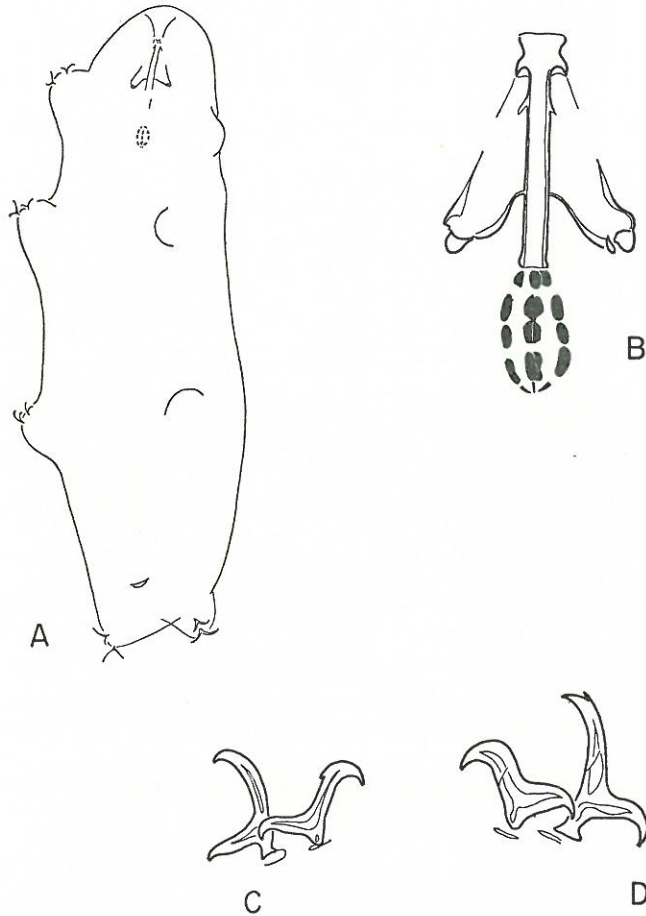


Fig. 18. *Hypsibius* (*I.*) *prosostomus*: A. Dorsal view. B. Mouthparts. C. Claws of leg II. D. Claws of leg IV.

The pharynx contains an apophysis, and two macroplacoids. The first macroplacoid is nearly twice as long as the second and is faintly divided.

This is a widely distributed species being known from Africa, Europe, North America, and South America. One California collection was from Shasta County, sample number 113C.

Hypsibius (*Hypsibius*) *convergens* (Urbanowicz, 1925)

(Fig. 22)

H. convergens is a species of moderate size somewhat over 400μ but usually less. The cuticle is generally smooth but may be rugose caudally. Eye spots are frequently present. The stylet supports are connected to the posterior one-half of the buccal tube. The apophysis is quite large and there are two macroplacoids. The macroplacoids may be short and thick or slightly elongate and rod-shaped. When

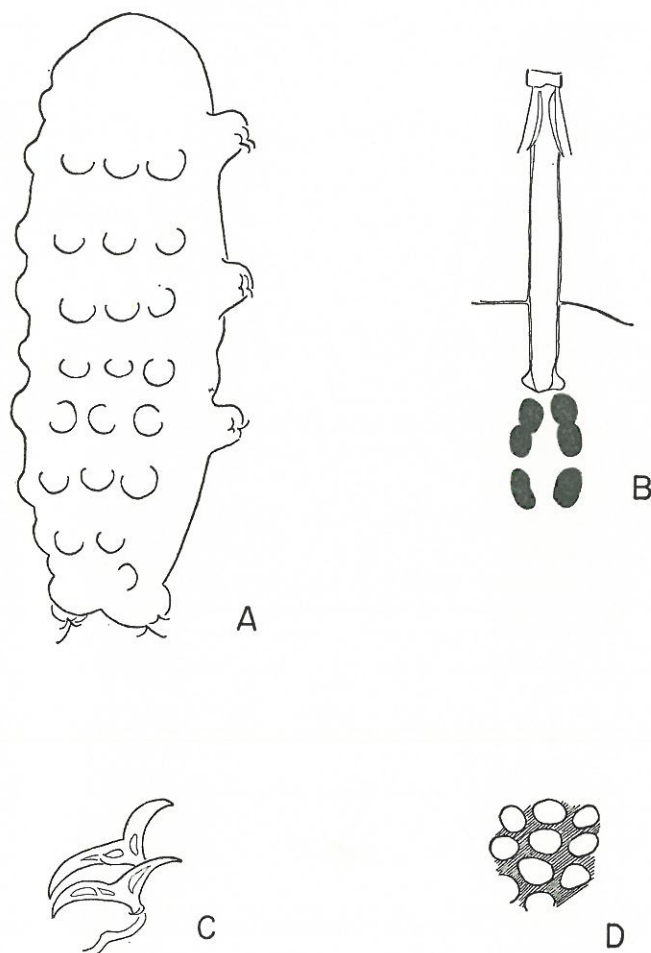


Fig. 19. *Hypsibius (I.) sattleri*: A. Dorsal view. B. Mouthparts.
C. Claws of leg II. D. Pattern of cuticle.

rod-shaped, the first macroplacoid may or may not appear transversely divided, but never separated. The principal branches of the claws of all legs are narrower toward the apex than they are basally. Eggs are deposited in the cuticle, and cysts may be formed.

This is a cosmopolitan species with a reported distribution including Africa, Europe, North America, and South America. There is considerable variation among specimens placed in this species, particularly in the length of the pharyngeal tube and some of the determinations are questionable. Assigned to this species were about 100 specimens from California, Oregon, and Washington localities 8A, C; 17; 18D; 24; 33; 34A; 46B; 48; 54; 55B; 68; 78; 83; 91; 109C, E; 115A, B, C; 118; 120E; 131A; 138A; 140A, C; 148A; 149; 150B; 151B; 166D; 172; 179; 181; 188; 202; 209A; 215B; 218A, B; 219C, D.

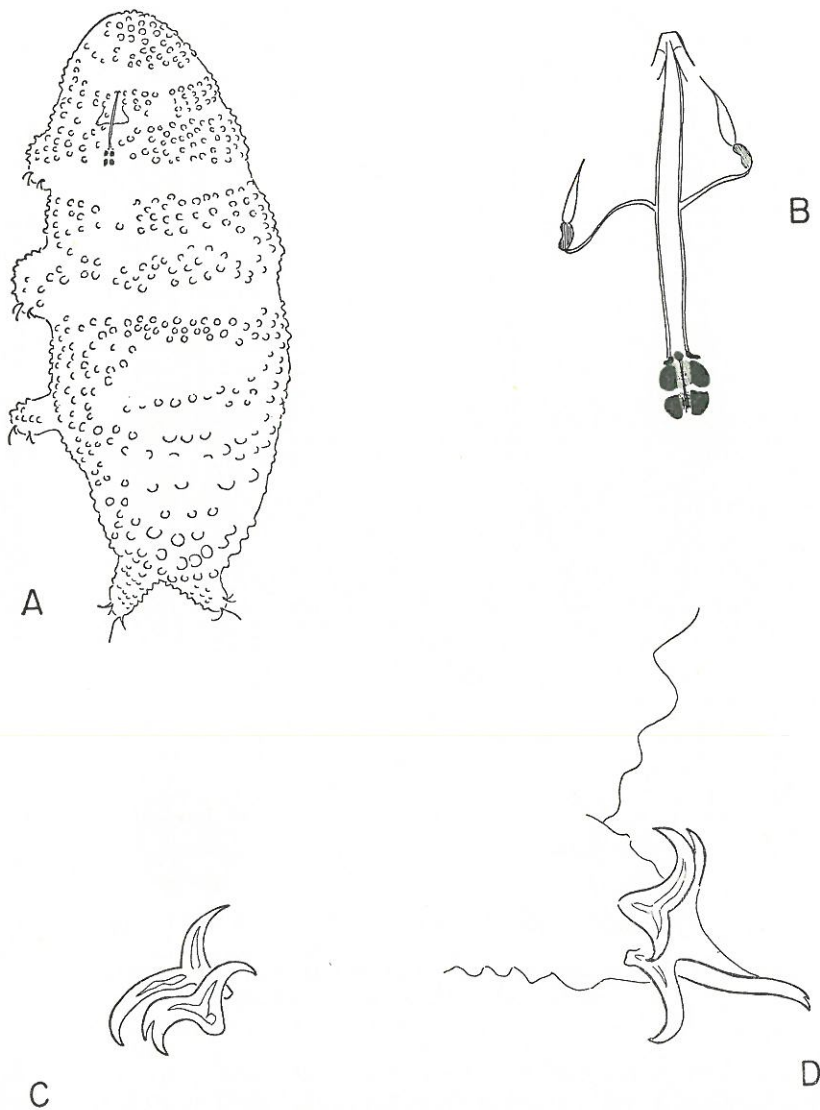


Fig. 20. *Hypsibius* (*H.*) *calcaratus*: A. Dorsal view. B. Mouthparts. C. Claws of leg II. D. Claws of leg IV.

Hypsibius (*Hypsibius*) *oberhaeuseri* (Doyère, 1840)

(Fig. 23)

H. oberhaeuseri is a species of moderate size, attaining a length of slightly over 400μ . The cuticle may appear smooth, faintly or distinctly granular. Eye spots may be present. The granulation is dispersed in longitudinal and transverse bands and is more pronounced posteriorly. The stylet supports are connected to the

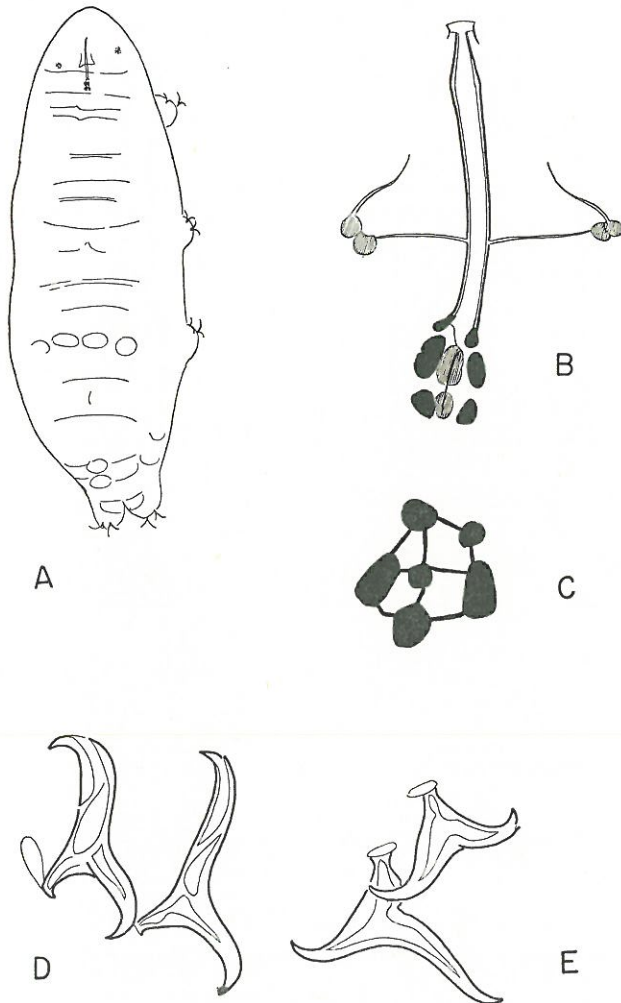


Fig. 21. *Hypsibius* (I.) *tuberculatus*: A. Dorsal view. B. Mouthparts. C. Sculpture. D. Claws of leg III. E. Claws of leg IV.

mouth at about one-half the length of the tube. The apophyses are large and there are two short, thick macroplacoids, subequal in size. The principal branches of the claws on all four legs are uniformly thin, much thinner at their bases than is the case for *H. convergens*. Eggs are deposited individually.

Approximately 360 specimens were prepared from Arizona, California, Oregon, and Washington collections: 2A, B; 12A, B; 13; 15A; 18A; 19; 20A, B; 21; 25; 26; 28; 30; 31; 32; 33; 48; 62; 64; 65; 68; 71; 73; 77; 79B; 81; 82B; 90; 92; 95; 98; 100; 103; 104; 106B; 108; 110B; 112; 114; 117; 122B; 125C; 127; 138B; 140A; 142; 144; 145; 149; 150B; 153; 162; 163C, D, E, F; 164; 166C; 167; 168; 171B; 173A, B; 179; 180; 181; 188; 189; 194; 201; 205; 206; 208; 211B; 214; 218B, C; 219A, C, D.

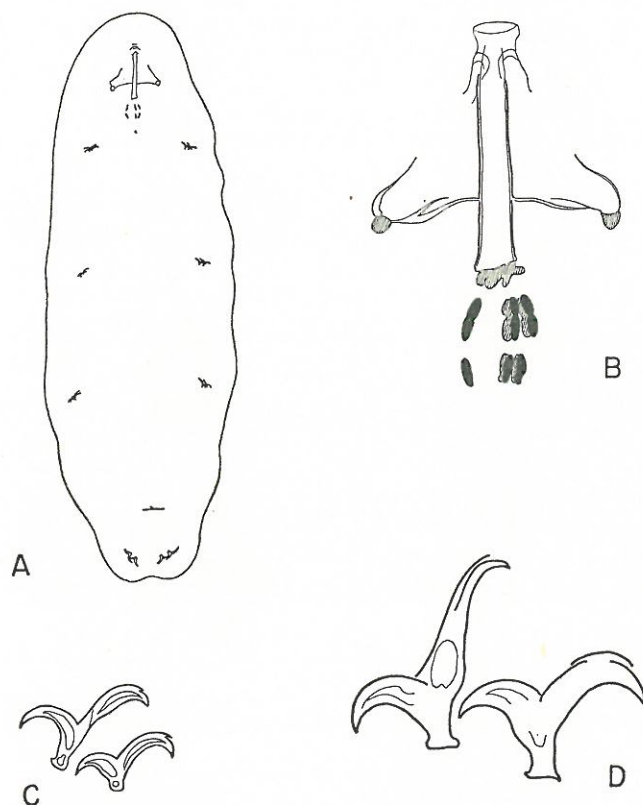


Fig. 22. *Hypsibius (H.) convergens*: A. Dorsal view. B. Mouthparts. C. Claws of leg III. D. Claws of leg IV.

Hypsibius (Isohypsibius) augusti (Murray, 1907)

(Fig. 24)

This species may attain a length of 900μ , but the largest examples that we have seen measure only 730μ . The two long thin macroplacoids and the slender claws, of which both branches are very long, distinguish this species. The eggs are laid in the old cuticle. We have one example containing 23 eggs.

H. augusti is reported to be cosmopolitan. It has been collected in California at localities 12C and 14.

Hypsibius (Isohypsibius) canadensis (Murray, 1910)

This species has been reported from California (Mathews, 1938) but has not been recognized in material collected during this survey. Superficially it resembles *H. (I.) prosostomus*, but the buccal tube is thinner, and the macroplacoids increase in size from first to third. Also, the cuticular thickening near the claw is absent.

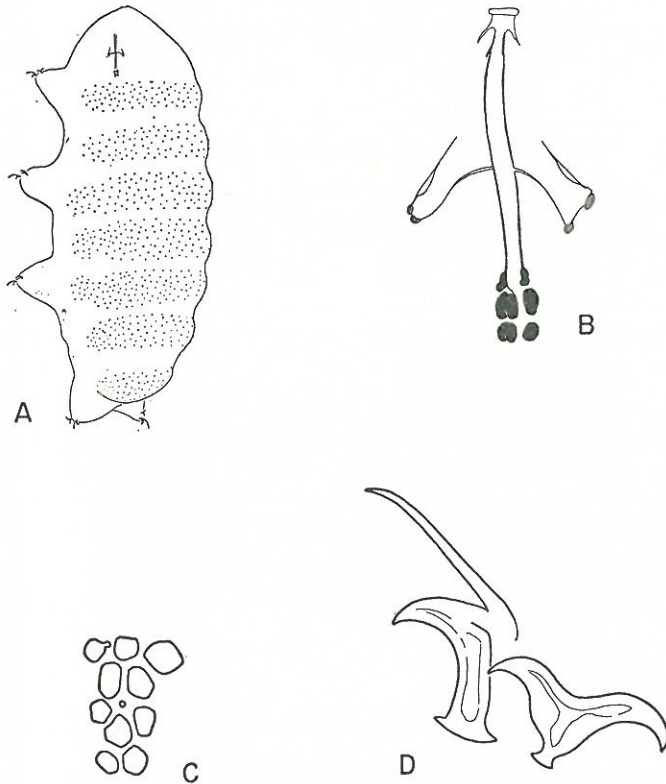


Fig. 23. *Hypsibius* (*H.*) *oberhaeuseri*: A. Dorsolateral view (longitudinal banding not evident for cleared specimens). B. Mouthparts. C. Sculpture of cuticle. D. Claws of leg IV.

Milnesiidae Ramazzotti, 1962

Milnesium Doyère, 1840

Milnesium tardigradum Doyère, 1840

(Fig. 25)

The genus *Milnesium* has but one species, *M. tardigradum*. It is cosmopolitan on land and enjoys the widest distribution of any species in western North America. It is a large species and is reported to be predacious. It seems to be equally abundant in the xeric conditions of the valley areas of California or in the moist north coastal regions. It has been recovered from moss and lichen, but never from aquatic samples.

The color, when alive and in water, varies from transparent to pinkish white. In isopropanol it is frequently purple. Eye spots may or may not be present. Eggs are found in groups, usually in excess of seven, within the cuticle which is identifiable by the claws.

Specific collection sites for about 500 specimens are as follows: 1; 2A, B; 5A, C; 6B; 12A, B; 16; 18A, B, C; 19B; 20B; 23; 26A; 28A; 30; 31; 32; 34A; 35; 38A; 39;

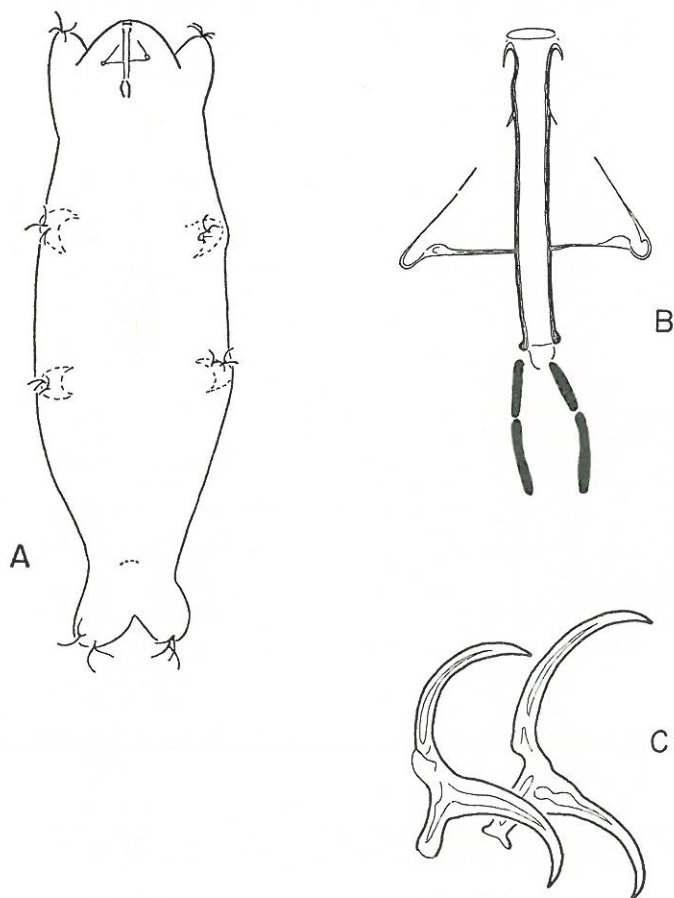


Fig. 24. *Hypsibius* (*I.*) *augusti*: A. Dorsal view. B. Mouthparts.
C. Claws of leg IV.

42; 44A; 45A, B; 51A, B; 52; 53; 55A; 57; 60; 64; 65; 66A; 68; 72; 73; 75A, B; 76; 77; 78; 79A; 82A, B, C; 87; 94; 95; 96; 97; 98A; 102A; 104A, B; 106; 107B; 108B; 109A, D; 110A, B, C; 112A; 113C; 114; 117; 119; 121; 122A, B; 123; 124B; 125; 126B; 127; 128; 131A; 136; 137; 138A, B, C; 139A, B, C; 140A, B, C; 142A, C; 145; 148A; 149; 151A; 152; 157; 159; 161; 162; 163A, B, C, D; 165A; 166A, D; 167; 168; 169; 171A; 174; 176; 178; 179; 183; 184; 188; 193; 194; 199; 200; 204A, B; 205; 206; 208; 210; 211A; 212; 213A, B, C; 214; 215A; 216; 218A, B, C; 219A.

Halechiniscidae Ramazzotti, 1962²

Styraconyx sargassi (Thulin, 1942)

This is a small marine species recorded from California as *Bathyechiniscus tetronyx* and referred to *Styraconyx* by Ramazzotti (1962). We have not seen examples of this species.

² This family is cited by Ramazzotti (1962) as "Halechiniscidae, Puglia, 1959," as the correct name for Onychopodidae Marcus, 1934. The correction was proposed by Puglia in a thesis, and the first publication appears to be that of Ramazzotti.

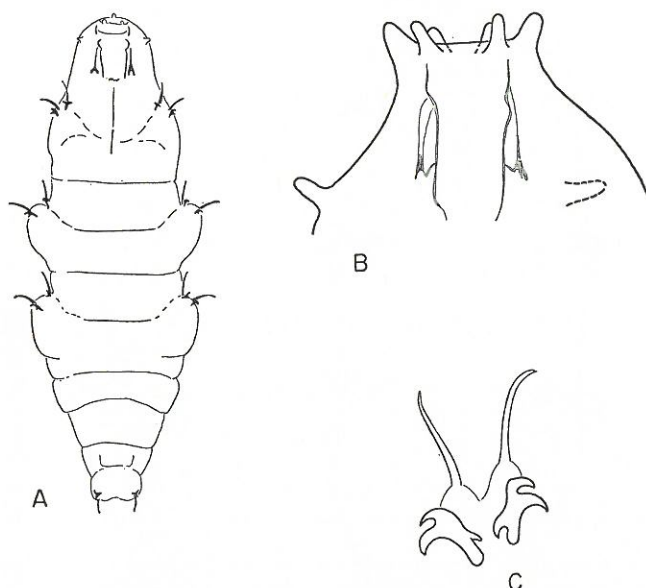


Fig. 25. *Milnesium tardigradum*: A. Dorsal view. B. Head with papillae and mouthparts. C. Claws.

Oreellidae Ramazzotti, 1962³

Echiniscoides sigismundi (M. Schultze, 1865)

(Fig. 26)

Although the literature points to algae on barnacles as the preferred habitat, specimens were also quite abundant in filamentous algae on rock. Occasional specimens were taken in association with mussels having evident algal growth on their shells, and in brown algae. The color of individuals varied from white to green or brown to reddish, with green (or transparent with internal green globules) being most common. Approximately 1 liter of alga-covered barnacles and 250 milliliters of algae yielded in excess of 100 specimens, of which 79 were mounted for study.

The species appears to be cosmopolitan in littoral habitats and is easily recognized by the claws of each leg which exceed four in number. The cuticle (Ramazzotti, 1962) is said to be smooth; however, careful observation shows the cuticle of our specimens to be covered by rows of fine granules.

Our collection was made at Dillon Beach (sample 47A) but the species is presumed to occur along much of the coast of western North America.

Echiniscidae Thulin, 1928

Echiniscus C.A.S. Schultze, 1840

This genus is easily recognized by the pattern of plates covering the dorsum (fig. 27). The terminal plate (E) is directly behind D or separated from D by one or

³ This name is attributed by Ramazzotti to an unpublished thesis by Puglia. It replaces *Nudechiniscidae* Marcus, 1934.

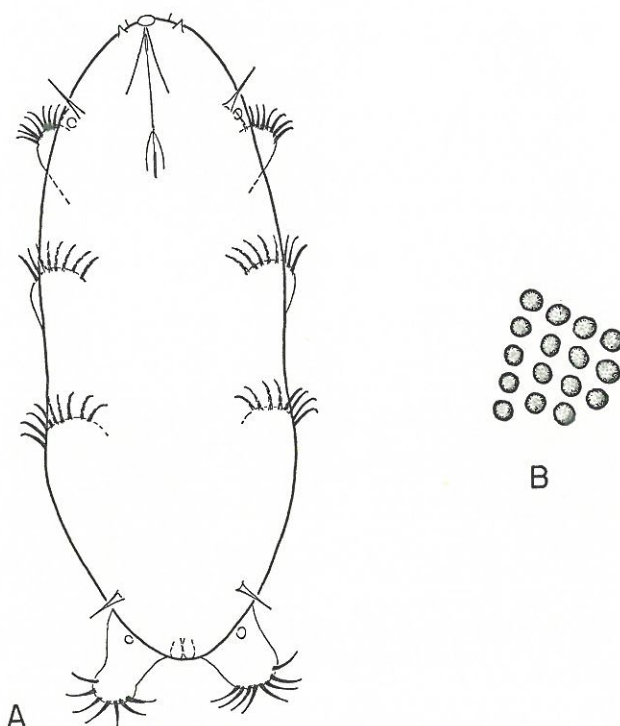


Fig. 26. *Echiniscoides sigismundi*: A. Dorsal view. B. Granulation of cuticle.

two intersegmental plates. A lateral spine is present at A, and spines may be present in the other positions. The four claws of each leg arise independently. About 95 species, subspecies, and varieties of *Echiniscus* have been proposed. Twelve species have been distinguished in our collections.

KEY TO SPECIES OF *ECHINISCUS*

- | | | |
|------|---|-------------------------------|
| 1 | Dorsum without median spine | 2 |
| | Dorsum with median spine | <i>E. (H.) gladiator</i> |
| 2(1) | Long lateral or dorsal spines additional to spine A present..... | 3 |
| | Long lateral or dorsal spines additional to spine A absent..... | 11 |
| 3(2) | End plate (E) with long lateral spines..... | 4 |
| | End plate (E) without long lateral spines..... | 7 |
| 4(3) | Lateral spines subequal to length of plates..... | 5 |
| | Lateral spines two or three times length of plates..... | 6 |
| 5(4) | Plates with irregular circular pitting..... | <i>E. (E.) quadrispinosus</i> |
| | Plates with regular polygonal pattern..... | <i>E. (E.) multispinosus</i> |
| 6(4) | Plates with irregular circular pitting, lateral spine D absent..... | <i>E. (E.) testudo</i> |
| | Plates with regular polygonal pattern; lateral spine D present..... | <i>E. (E.) oihonnae</i> |
| 7(3) | Lateral spines present at B, C, and D with B sometimes absent..... | 8 |
| | Lateral spines present at D only or absent..... | 9 |
| 8(7) | Lateral spine B long, subequal to other lateral spines..... | <i>E. (E.) blumi</i> |
| | Lateral spine B short or absent..... | <i>E. (E.) trisetosus</i> |
| 9(7) | Lateral spine D present | 10 |
| | Lateral spine D absent | <i>E. (E.) canadensis</i> |

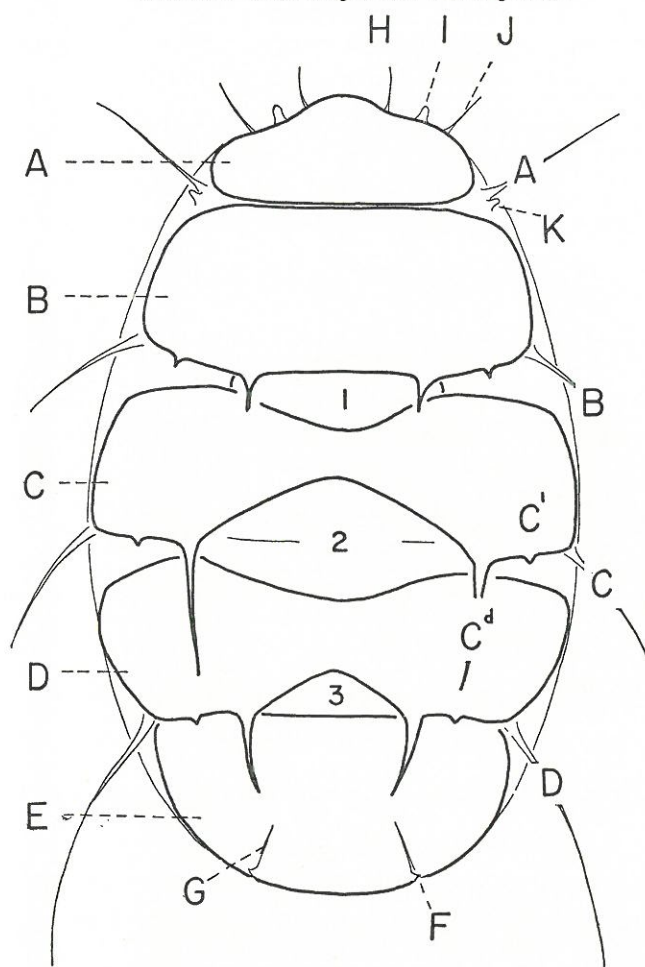


Fig. 27. Dorsal aspect of genus *Echiniscus*. *A* through *E* (left side), dorsal plates. *A*. Plate *A* or head plate. *B*. Plate *B* or scapular plate. *C*. Plate *C*. *D*. Plate *D*. *E*. Plate *E*. End plate or terminal plate. *G*. Furrow or incision of late *E*. *A* through *D* (right side), lateral spines associated with plates and referred to them by the same letters (a lateral spine may be present at *E* also). Median spines are identified by plate letter and superscript ^d and those more lateral by the symbol prime—as examples *C*^d and *C'*. *F*. A minute spine, not considered as a lateral spine. *H*. Internal buccal spine or cirrus. *I*. Buccal papilla. *J*. External buccal spine or cirrus. *K*. Clava. 1. Intersegmental or medial plate one. 2. Intersegmental plate two. 3. Intersegmental plate three.

- 10(9) Dorsal spines present*E. (E.) trisetosus*
 Dorsal spines absent*E. (E.) robertsi*
 11(2) Spine *A* much shorter than length of dorsum, spur on inner claw of leg IV well
 developed 12
 Spine *A* subequal to length of dorsum, spur of inner claw of leg IV weak...*E. (E.) wendti*
 12(11) Sculpture uniform*E. (E.) arctomys*
 Sculpture diverse, one or more undescribed species near.....*E. (E.) merokonensis*

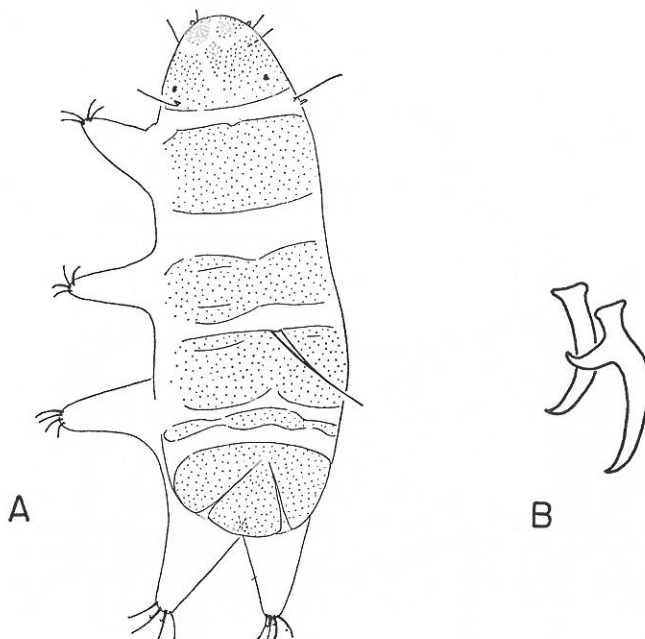


Fig. 28. *Echiniscus* (*H.*) *gladiator*: A. Dorsal view. B. Claws of leg IV.

Echiniscus (*Hypechiniscus*) *gladiator* J. Murray, 1905

(Fig. 28)

This is a species of moderate size (up to 300μ). In the few examples that we have seen, the dorsal plating is weakly defined, and the cuticle finely granulate. The species is most easily distinguished by the single median dorsal spine and by the terminal plate which appears to be divided into three subequal parts. Lateral spines, except at A, are lacking. The inner claw of leg IV bears a large basal spur.

Ramazzotti (1962) reports a limited distribution of the species in Canada, Europe, Greenland, New Zealand, and United States. We have seen specimens from sites 0, 99A, and 201 in Alaska, California, and Oregon.

Echiniscus (*Echiniscus*) *quadrispinosus* Richters, 1902

(Fig. 29)

This is a rather small species, being less than 300μ . Lateral spines are lacking at B, but present at A, C, D, and E. Smaller dorsal spines are present at C^d and D^d. Transverse and median smooth areas are present on plates B and E. Elsewhere the sculpture of the cuticle consists of irregular-sized pitting. The inner claws have spurs, the outer claws are simple.

We have seen only a single California specimen collected at site 129. The species is cited from Africa, the Canaries, Europe, North America, and South America.

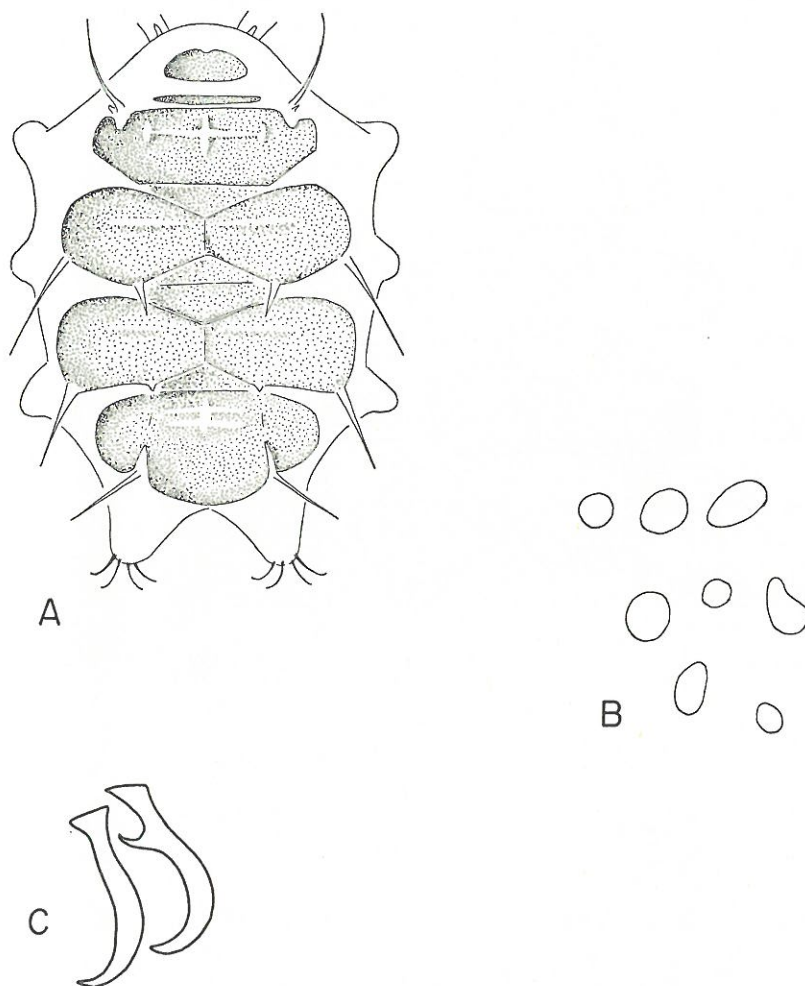


Fig. 29. *Echiniscus (E.) quadrispinosus*: A. Dorsal view. B. Pattern of cuticle.
C. Claws of leg IV.

Echiniscus (Echiniscus) multispinosus Cunha, 1944

(Fig. 30)

Echiniscus multispinosus is small, approaching 250μ in length. All plates have lateral spines, some of which have a tendency to have secondary points or barbs. Dorsal spines are present at all positions, and lateral spines at all except B. The cuticle is composed of polygons with occasional irregular clear areas between them, which appear as pores at high focus. The inner claws of the legs have large, basally directed spurs. The outer claw is usually without a spur, but some specimens may possess a small one. Plate E is transversely indented.

This species is similar to *E. quadrispinosus* in body size and length of spines. However, *E. multispinosus* has small spines between the lateral and dorsal spines

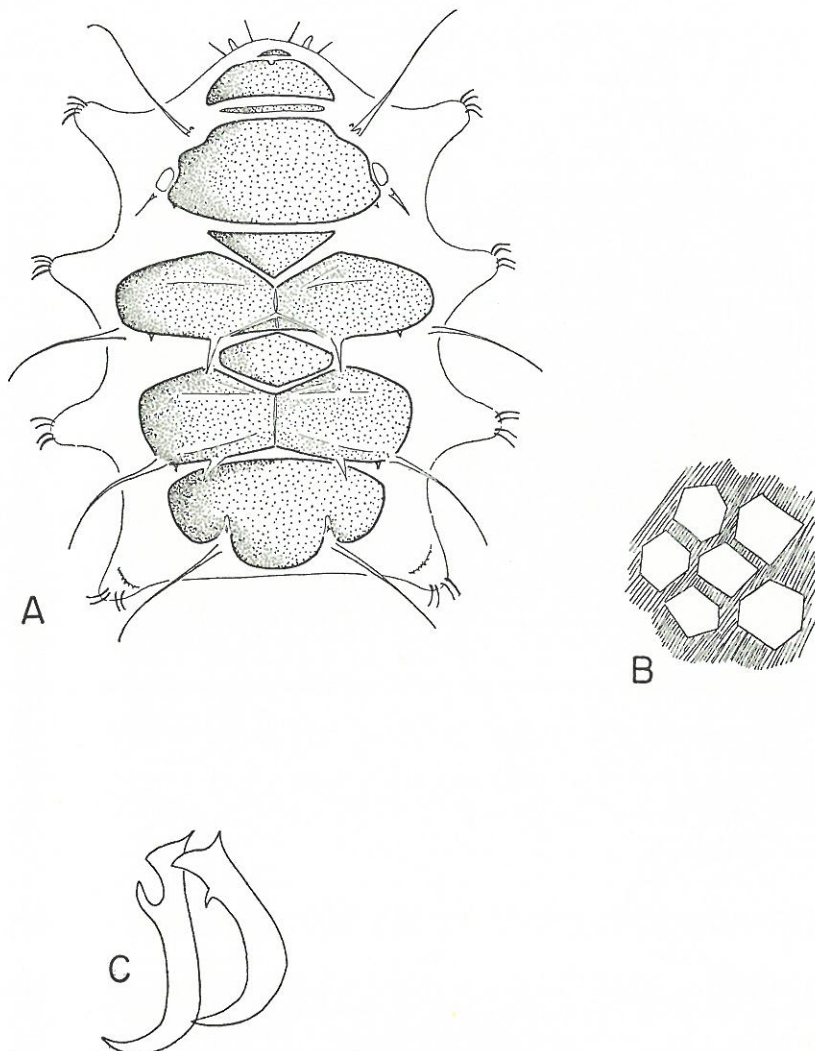


Fig. 30. *Echiniscus (E.) multispinosus*: A. Dorsal view. B. Pattern of cuticle.
C. Claws of leg IV.

on segments B, C, and D, and a small spine in the incision near the base of spine E.

Specimens were recovered from California and Oregon localities 49; 52; 104C; 174; and 195.

Echiniscus (Echiniscus) testudo (Doyère, 1840)

(Fig. 31)

This species is of moderate size, reaching a length in excess of 350 μ . Two varieties are recognized by Ramazzotti. *E. testudo* var. *trifilis* has lateral spines at positions A, C, and E, whereas *E. testudo* var. *quadrifilis* has spines at A, B, C, and E. We have seen only specimens of the variety *quadrifilis* from three collections at high elevations. The cuticle of the specimens from California is irregularly

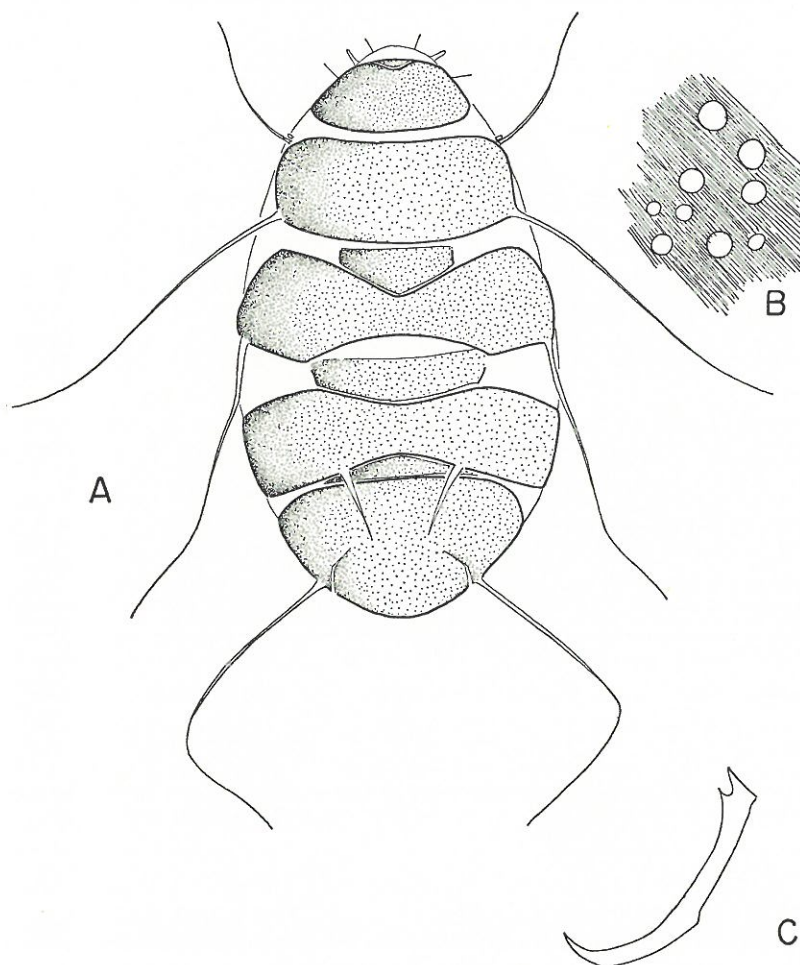


Fig. 31. *Echiniscus (E.) testudo*: A. Dorsal view. B. Pattern of cuticle.
C. Inner claw of leg IV.

pitted, but Ramazzotti (1962) reports a polygonal pattern as well. The inner claw of leg IV has an obvious basal spur. It is reduced or absent on the claws of legs I-III.

Echiniscus testudo has been reported from Europe and North America. We have observed specimens from California and Nevada localities 64, 127, and 171A.

Echiniscus (Echiniscus) oihonnae Richters, 1903

(Fig. 32)

Our specimens have reduced dorsal spines and no spines at B. The stylet supports are visible in most preparations and aid in the determination of this species.

Echiniscus oihonnae is known from Australia, Europe, and North America. In California, 20 specimens were mounted from a collection near Riverton (sample 20A).

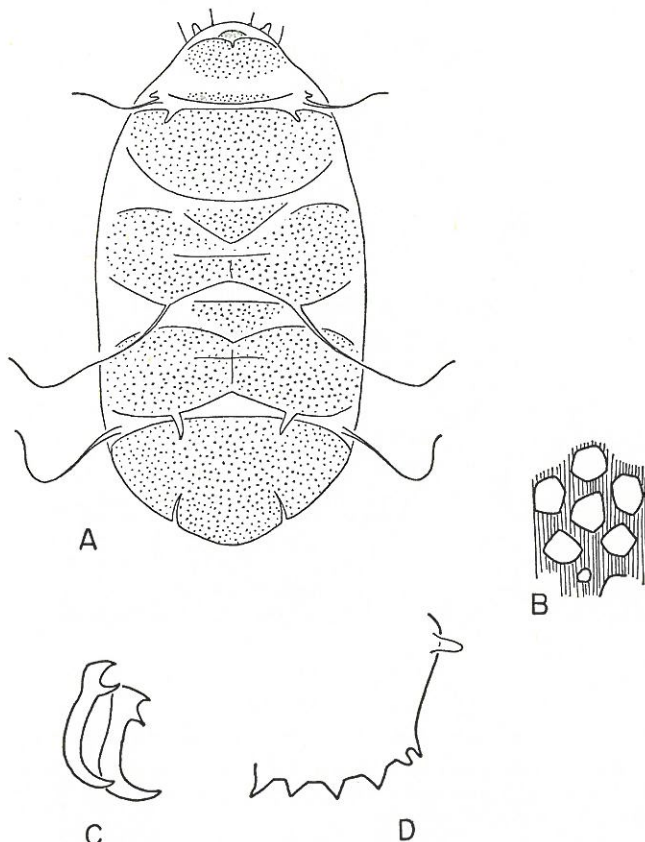


Fig. 34. *Echiniscus (E.) trisetosus*: A. Dorsal view. B. Pattern of cuticle. C. Claws of leg IV. D. Collar and papilla of leg of IV.

Echiniscus (Echiniscus) canadensis J. Murray, 1910

(Fig. 36)

This moderate sized species (approximately 300μ) has the cuticle sculptured with polygons enclosing a central spot. In respect to the cuticular sculpture it is similar to *E. blumi* and *E. trisetosus*. *E. canadensis* is characterized by spines at A, C^d, and D^d, with C^d being longer than D^d. One of the buccal spines is occasionally bifid. The inner claws of all legs have a basal spur. The outer claws of legs I–III are simple while that of leg IV may have one or two spurs.

Ramazzotti (1962) reports the species to be widespread in Europe, Korea, and from Vancouver Island and Illinois in North America. We have seen eight specimens from localities 82B and 99.

***Echiniscus (Echiniscus) robertsi* Schuster and Grigarick, new species**

(Fig. 37)

Length 148μ exclusive of leg IV. Eyes present. Pattern of cuticular plates comprising well defined polygons, not interconnected. Head plate divided with anterior

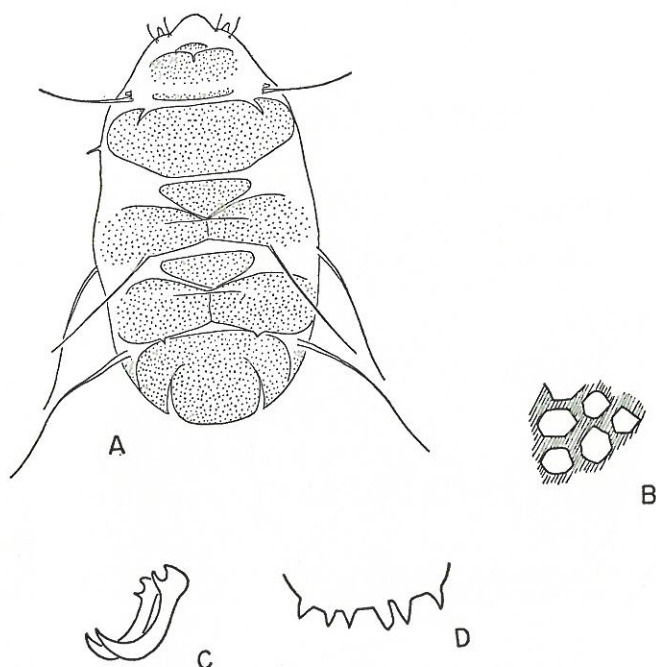


Fig. 35. Alternate form of *Echiniscus* (*E.*) *trisetosus*: A. Dorsal view. B. Pattern of cuticle. C. Claws of leg IV. D. Collar of leg IV.

section small and posterior large; front margin of posterior section deeply and narrowly emarginate at center. Plate B with lateral areas not forming separate platelets. Median plate 1 entire and sculptured. Plates C and D medianly divided and seemingly transversely divided because of areas of weak sculpture. Median plate 2 with sculpture of anterior section small and indistinct, posterior section large and prominent. Median plate 3 entire. End plate with feeble incision, without spine E. Sculpture of plates is larger and more pronounced on posterior half of plate B, median areas of C and D, median plates 1 and 2, and transversely on anterior half of end plate. Leg plates absent. Spine A 42μ and D 25μ . Leg I with small conical projection, IV with larger rounded papilla. Collar of leg IV consisting of five or six teeth. Inner claws of legs I and III with large basally directed spurs, spur of leg IV recurved; outer claws simple.

The holotype and four paratypes were recovered from a mixture of cryptogams from a bog at Sand Point, Popof Island, Alaska, collected by Warren G. Roberts in mid-June, 1963. The type series is deposited in the Department of Entomology, Davis. The holotype is mounted in Hoyer's.

The presence in larger individuals of lateral spines which are limited to positions A and D distinguish this species from all others. The five specimens are approximately 124μ , 134μ , 148μ , 148μ , and 200μ , in length, with spine D occurring on the three largest specimens but not on the smaller ones. The egg and, presumably, first instar are unknown.

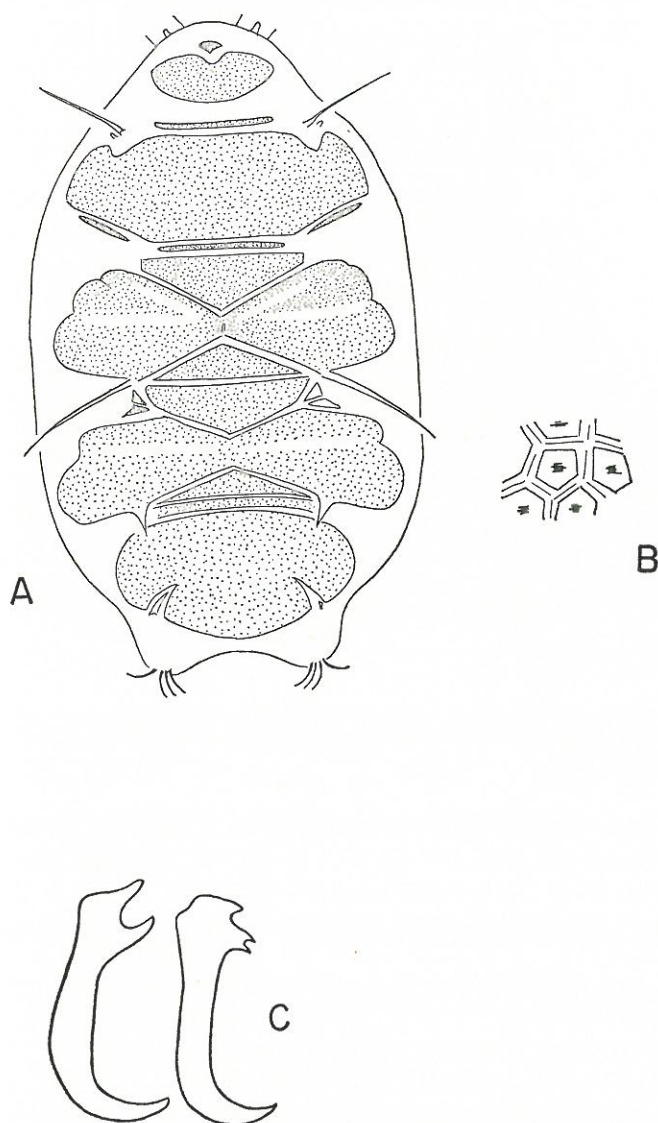


Fig. 36. *Echiniscus (E.) canadensis*: A. Dorsal view. B. Pattern of cuticle. C. Claws of leg IV.

Echiniscus (Echiniscus) wendti Richters, 1903

(Fig. 38)

This is a species of small to moderate size, up to about 300 μ . Eye spots are present. The only lateral spines are at A and they are nearly as long as the body. On plates B and C, transversely and in the front half, the sculpture is less pronounced. Median plate 3 may be absent although it appears to be a well-defined area. The anterior legs have a short spine, and the interior claws of each leg have a spur.

The placement of this species depends on whether the end plate is indistinctly

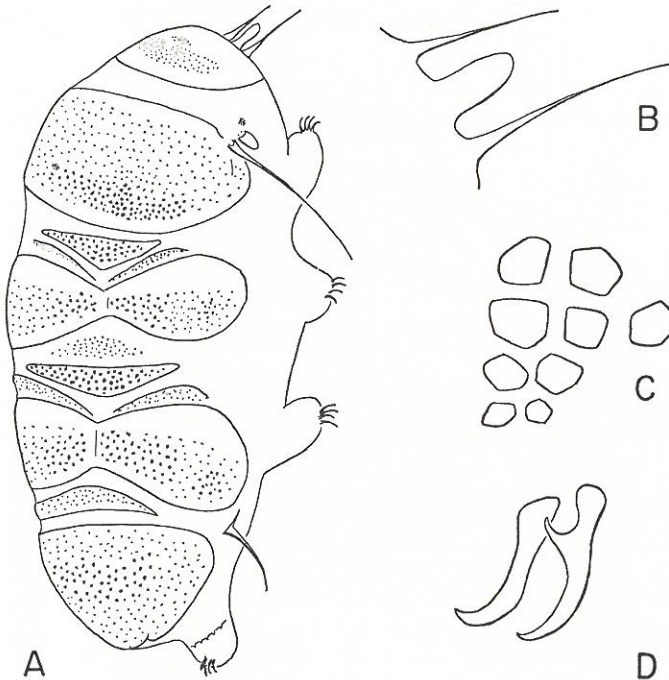


Fig. 37. *Echiniscus (E.) robertsi* n. sp.: A. Dorsal view. B. Buccal spines and papilla. C. Polygonal pattern of cuticle. D. Claws of leg IV.

faceted or not faceted at all, and on whether the median plate 3 is present or absent and the area merely sculptured. Specimens of the California series have been determined as both *E. wendti* and *E. reticulatus* by different authorities. It is remotely possible that neither interpretation is correct because the available specimens have a short spine on leg I instead of the long spine as illustrated for *E. reticulatus* (Murray, 1905), and they have also the spur of the internal claw basal and short, inconsistent for *E. wendti*.

E. wendti is cosmopolitan, being recorded from the Arctic and Antarctic, Europe, North America, and South America. California specimens were collected at Beckwourth Mtn., Plumas County, sample 85A.

Echiniscus (Echiniscus) arctomys Ehrenberg, 1853

(Fig. 39)

Small species, usually less than 300 μ . Eye spots are present. The sculpture of the plates is uniform, less pronounced at the front of the plates B and C. The only lateral spine is at A, and is of moderate length, less than 50 per cent as long as the body. Median plate 3 is absent although the area may be sculptured. The inner claws of all legs have spurs.

E. arctomys is a cosmopolitan species. It has been collected twice in California at localities 21B and 88.

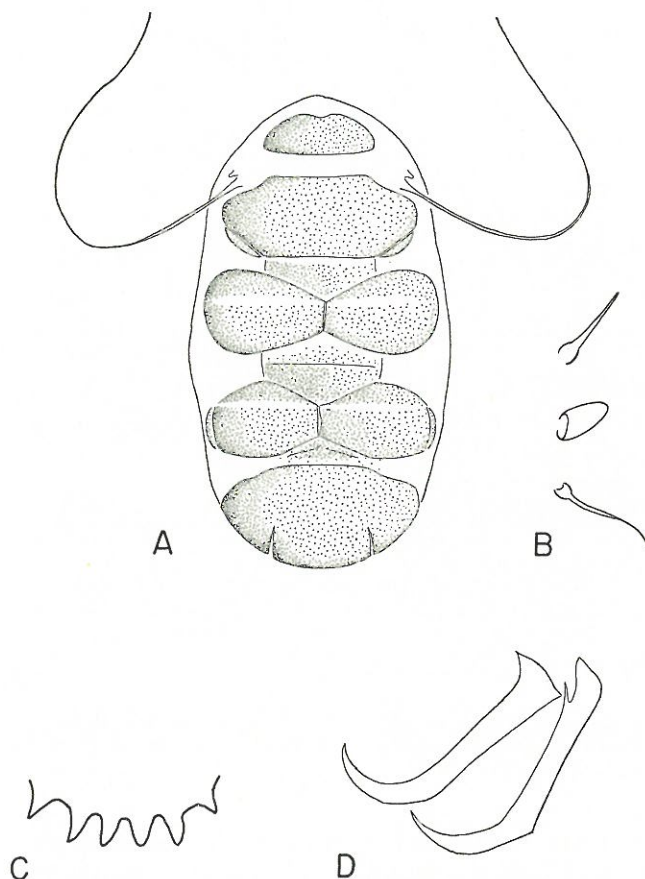


Fig. 38. *Echiniscus* (*E.*) *wendti*: A. Dorsal view. B. Cephalic appendages. C. Collar of leg IV. D. Claws of leg IV.

Echiniscus (*Echiniscus*) sp. near *kerguelensis*

(Fig. 40)

This is the most prevalent species of *Echiniscus* in this area and it may be undescribed. The sculpture varies between samples from different localities as does the development of dorsal spines at C^d and D^d. The apparent complexity of the problem, especially in view of the similarity of these populations to already described species, has prompted us to make no decision at present, thus setting the problem aside. We have loaned the series of about 350 specimens to Dr. Mihelčič for further study.

Pseudechiniscus Thulin, 1911

This genus resembles *Echiniscus* in that the dorsum is covered by distinct plates. The terminal plate (E) is separated from D by a transverse pseudosegmental plate.

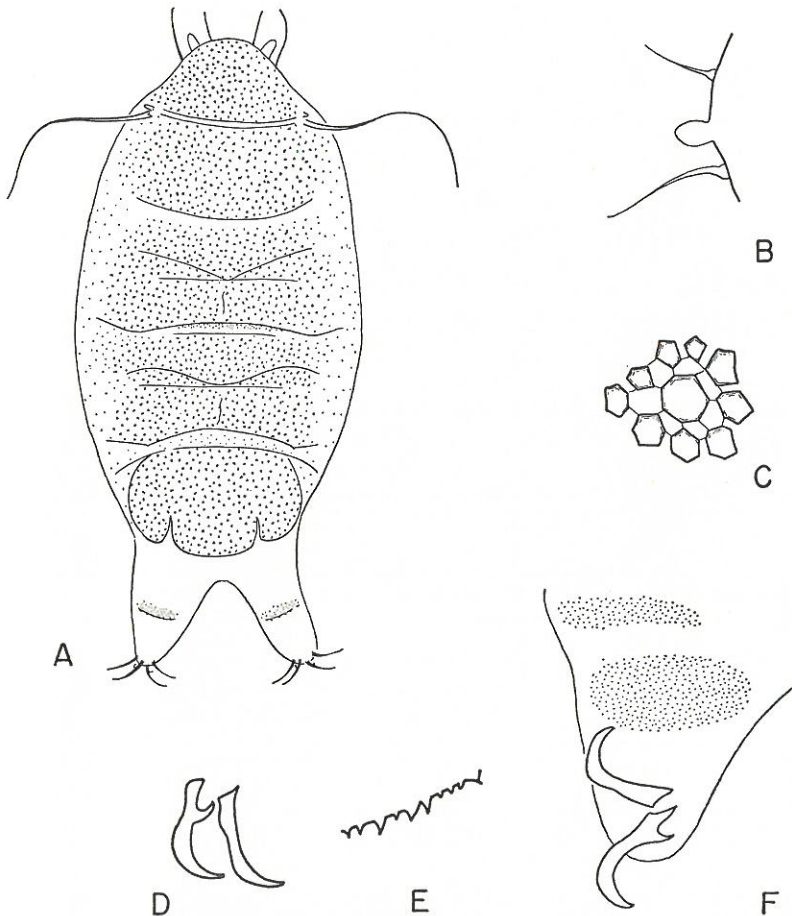


Fig. 39. *Echiniscus (E.) arctomys*: A. Dorsal view. B. Cephalic appendages. C. Polygonal pattern of cuticle. D. Claws of leg IV. E. Collar of leg IV. F. Leg plates.

KEY TO SPECIES OF *PSEUDECHINISCUS*

- | | | |
|------|---|-------------------|
| 1 | Lateral spines present at positions B, C, and D..... | 2 |
| | Lateral spines at positions B, C, and D absent..... | <i>P. suillus</i> |
| 2(1) | Buccal cirri simple; dorsal spines absent | 3 |
| | Buccal cirri expanded distally; dorsal spines present..... | <i>P. victor</i> |
| 3(2) | Sculpture of dorsum with regular polygons..... | <i>P. raneyi</i> |
| | Sculpture of dorsum with sparse granules, plates bordered by denser, smaller granules | <i>P. goedeni</i> |

Pseudechiniscus suillus (Ehrenberg), 1853

Pseudechiniscus suillus has been reported from Santa Catalina Island, California, by Mathews (1938), but we have not recovered this species from the mainland. It would be easily recognized as it lacks lateral spines. The other species known to occur in western North America all have lateral spines at one or more positions. *P. suillus* is noted as having a cosmopolitan distribution.

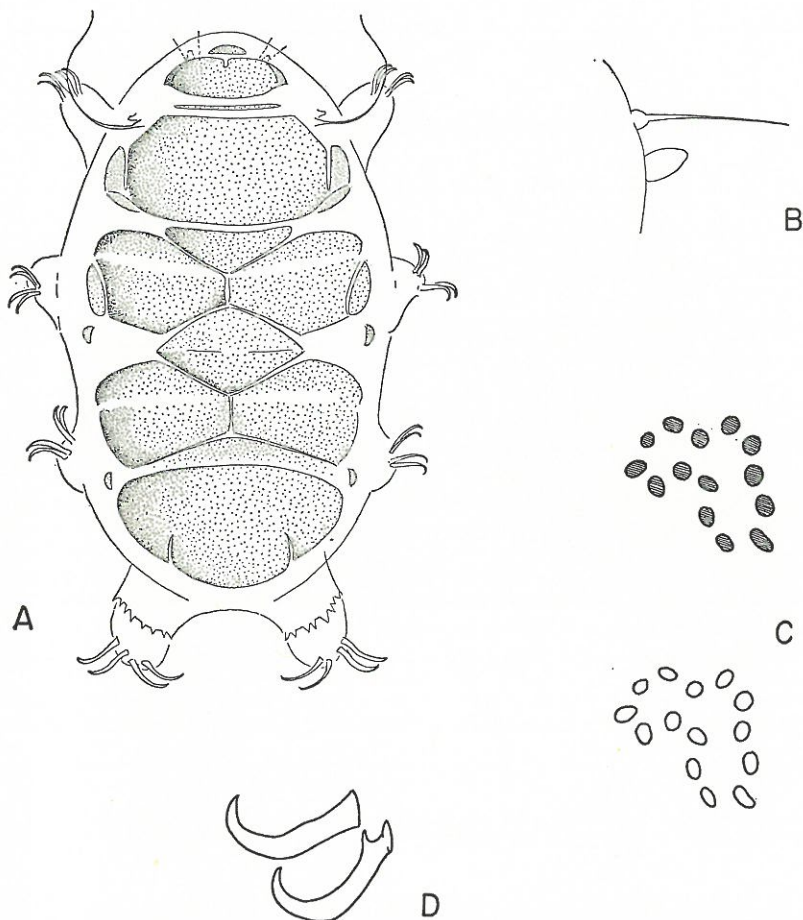


Fig. 40. *Echiniscus* (*E.*) sp. near *kerguelensis*: A. Dorsal view. B. Interior cephalic spine and papilla. C. Pattern of cuticle, high and low focus. D. Claws of leg IV.

Pseudechiniscus victor (Ehrenberg, 1853)

(Fig. 41)

The length is up to 310μ . Blackish eye spots are present. The sculpture of the plates is a regular punctation which extends to the intersegmental areas. The buccal cirri appear bifurcate and recurved distally. Lateral spines are present at A, B, C, D, and E and dorsally on C, or C and D, and also on the pseudo-segmental plate. The fourth pair of legs have dentate collars consisting of a few large teeth.

This species is known from Europe (Italy and the Alps, Monte Rosa and Cervino) from Greenland, and from various arctic localities. About 95 specimens were collected in California and Oregon at localities 120A, 126C, and 179.

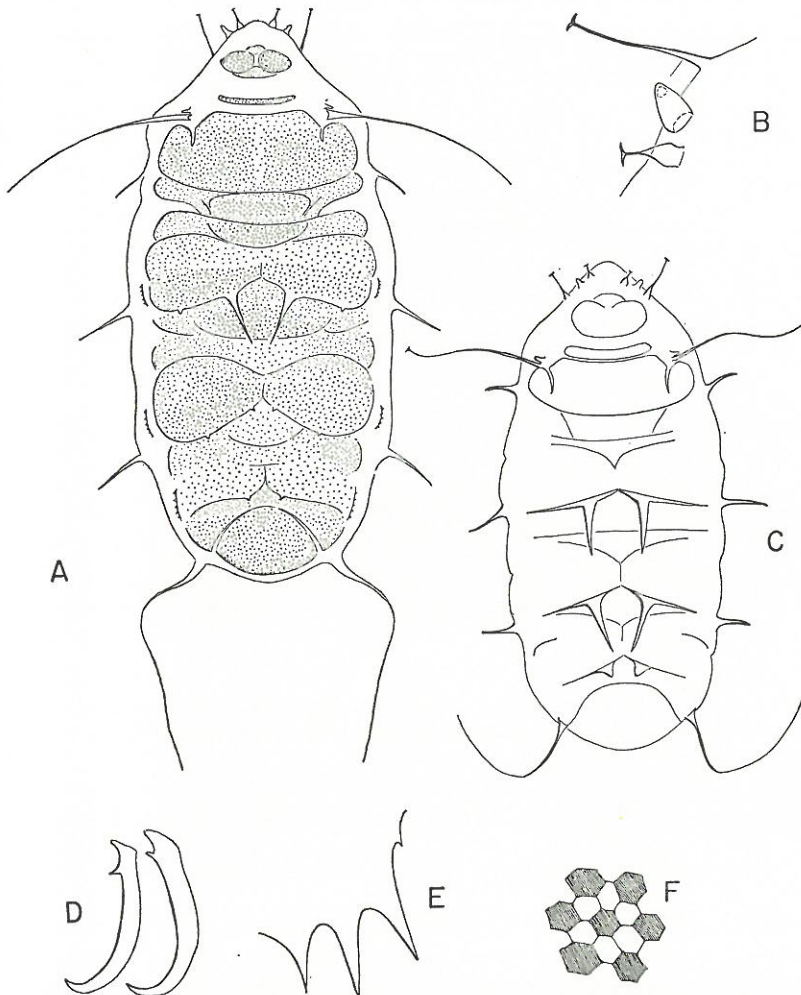


Fig. 41. *Pseudochiniscus victor*: A. Dorsal view of example with reduced spine D⁴. B. Cephalic appendages. C. Dorsal view of example with spine D⁴ developed. D. Claws of leg IV. E. Collar of leg IV. F. Pattern of cuticle.

Pseudechiniscus raneyi Grigarick, Mihelčič, and Schuster, 1964

(Fig. 42)

Specimens of this species are often about 300μ , with a length of 390μ the longest recorded. The cuticular sculpture is composed of polygons. The plates are distinct and especially plate B appears subdivided. Lateral spines are present in positions A, B, C, D, and E, with spines A and E considerably longer. Spines B, C, and D are subequal on individuals collected from the southernmost localities. Spine C on one or both sides may be almost as long as spine E on some individuals from the northern localities.

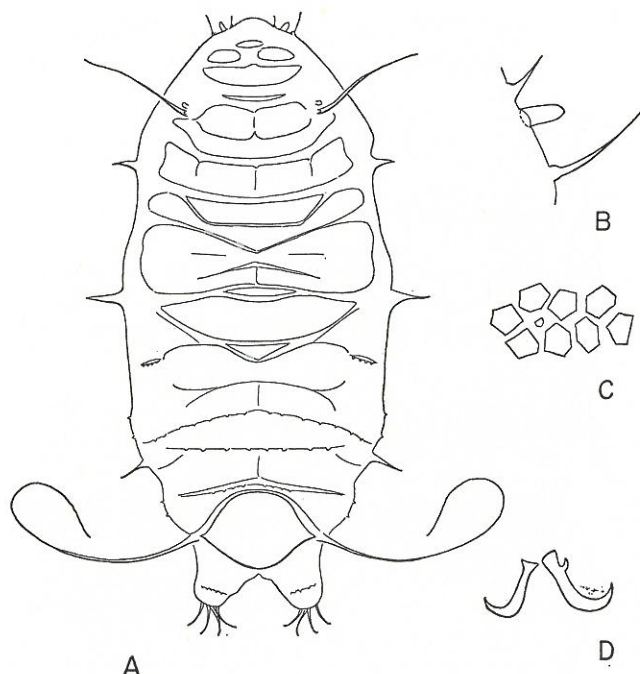


Fig. 42. *Pseudechiniscus raneyi*: A. Dorsal view. B. Buccal cirri and papilla. C. Pattern of cuticle. D. Claws of leg IV.

P. raneyi is known only from California and Oregon and has been collected at the following localities: 27A; 58; 111; 112A; 113C; 130; 160; 161; 204B.

Pseudechiniscus goedeni Grigarick, Mihelčič and Schuster, 1964

(Fig. 43)

Pseudechiniscus goedeni may attain a length of 450μ , but is usually no longer than 370μ . This species has spines subequal in length at all lateral positions and dorsally on the pseudosegmental plate. The plates are patterned with longitudinal and transverse rows of small, closely spaced granules enclosing areas where the granules are larger and more widely spaced.

P. goedeni is known only from the type collections at localities 195 and 197A in Oregon. Thirty-five specimens were available for study.

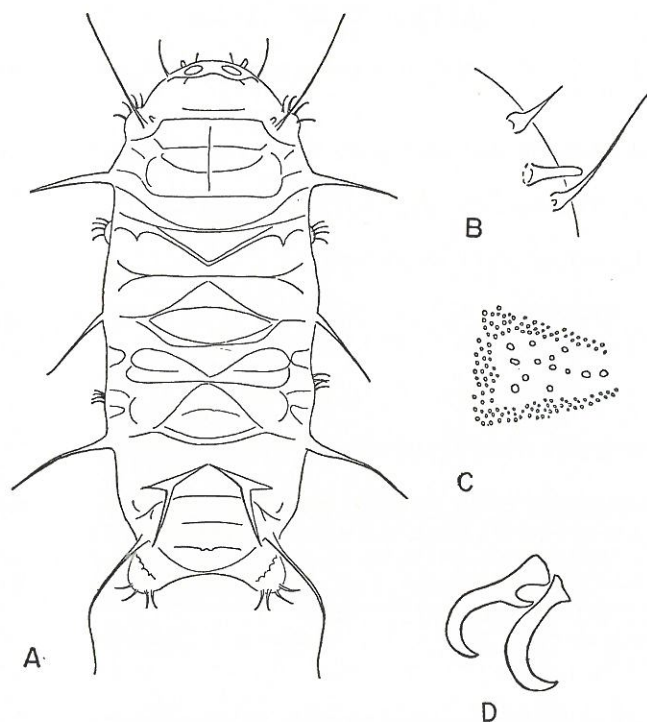


Fig. 43. *Pseudochiniscus goedeni*: A. Dorsal view. B. Buccal cirri and papilla. C. Pattern of cuticle. D. Claws of leg IV.

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