FRESHWATER ISOPODS (ASELLIDAE) OF NORTH AMERICA

U.S. Environmental Protection Agency
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Biological Methods Branch
Aquatic Biology Section
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by

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FOREWORD

This manual was originally published as Identification Manual No. 7, Biota of Freshwater Ecosystems, Water Pollution Control Research Series 18050 ELD05/72, U.S. Environmental Protection Agency. This series of manuals was prepared to improve the quality of the data upon which environmental decisions are based by providing biologists in the USEPA, and other Federal, state and private agencies with improved taxonomic guides for the identification of organisms collected in studies of aquatic ecosystems. Other groups of invertebrates for which manuals were prepared in this series include: branchiuran crustaceans (*Argulus*), amphipod crustaceans (Gammaridae), decapod crustaceans (Astacidae), leeches (Hirudinea), freshwater nematodes (Nematoda), polychaete worms (Polychaeta), freshwater planarians (Turbellaria), dryopoid beetles (Coleoptera), freshwater clams (Sphaeriacea), and freshwater mussels (Unionacea). The preparation of these documents was coordinated by the Oceanography and Limnology Program, Smithsonian Institution.

The manuals in the Biota of Freshwater Ecosystems series supplement identification manuals on the diatoms and midges prepared earlier by the Aquatic Biology Methods Development and Standardization Program, Environmental Monitoring & Support Laboratory-Cincinnati, Office of Research & Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, and will be made available from this office. The Aquatic Biology Section is responsible for the development, evaluation and standardization of methods for the collection of biological field and laboratory data by EPA regional, enforcement, and research programs engaged in inland, estuarine, and marine water quality and permit compliance monitoring, and other studies of the effects of pollutants on aquatic organisms, including the phytoplankton, zooplankton, periphyton, macrophyton, macroinvertebrates, and fish. The program addresses methods for: sample collection; sample preparation; organism identification and enumeration; the measurement of biomass, metabolic rates, and the bioaccumulation and pathology of toxic substances; bioassay; and the computerization, analysis, and interpretation of biological data. Biological methods recommended for use in the Federal water pollution control program are included in the manual, *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents*, published by our program.

Identification manuals have also been prepared or are currently in preparation or revision by our program for the following groups: naidids, tubificids, leeches, crustacean zooplankton, stoneflies, mayflies (Stenonema), centric diatoms, and blue-green algae. As companions to the biological methods manual and the taxonomic keys, water quality profiles have been developed or are in preparation for the freshwater diatoms, blue-green algae, midges, mayflies, stoneflies, caddisflies, and crustacean zooplankton.

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ABSTRACT

A key is given to the North American genera (*Asellus* and *Lirceus*) of asellid isopods. Another key is provided for the surface-living species of *Asellus* but lack of clear, published morphological distinctions in the genus *Lirceus* prevents the construction of a key for that genus. Notes on ecology, collection, preservation and identification are also included.

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SECTION I

INTRODUCTION

The Asellidae are the most important surface-living freshwater isopods in North America. The other isopod families which occur in North America, Bopyridae, Sphaeromatidae (formerly Sphaeromidae), and Cirolanidae, are much less important. The Bopyridae are parasitic forms, and the Cirolanidae are spring or underground forms occurring in Mexico, areas immediately to its north, and Virginia. The Sphaeromatidae, otherwise a predominantly marine family, includes several species found in fresh to brackish waters near the coast and in hot springs. Sphaeromatids and cirolanids are easily recognised by their uropods which are attached anterolaterally to the abdomen, and not, as in asellids, posteriorly or posterolaterally. None of these additional isopod families, all of whose representatives are only rarely or occasionally encountered in surface fresh waters of North America, is considered further in this publication.

The North American fauna of the Asellidae is not well-known, but Williams (1970) has revised the systematics of the surface-living species of *Asellus*, the principal genus, and the ecology of some asellids of known identity has also been studied recently (e.g. Ellis, 1961, 1971; Clifford, 1966; Styron, 1968; Seidenberg, 1969).

For the purposes of this report, North American asellids are considered to be represented by two genera, *Lirceus* and *Asellus*. Other generic names that have been applied include *Asellopsis*, *Mancasellus*, and *Caecidotea*. All species of these are now regarded as either species of *Lirceus* (=*Asellopsis*, *Mancasellus*) or *Asellus* (=*Caecidotea*). It has recently been proposed (Henry and Magniez, 1968, 1970) that North American *Asellus* species be divided between the genera *Conasellus*, *Asellus* (of restricted definition), and *Pseudobaicalasellus*. Of these, the first two represent the elevation of former 'subgenera' to generic rank, and the latter a newly proposed genus. It may well be that North American asellids will prove to be a group that should legitimately be regarded as representing several genera, but as the proposals of Henry and Magniez were published before adequate taxonomic consideration had been given surface-living species of North American asellids, and before systematic knowledge of surface-living and underground species has been integrated, such proposals seem decidedly premature to the present author. In order not to perpetuate at generic level the sort of confusion that has existed in part at 'subgeneric' level in North American asellids (*see* Williams, 1970, p. 2), the most practical procedure for the moment is to regard all North American species as referable to two genera only, *Asellus* as defined by Birstein (1951, p. 51), and *Lirceus*. The former contains both surface-living and underground species; species of the latter typically live in surface waters only.

Lirceus was revised taxonomically by Hubricht and Mackin (1949) who included a key, but the revision is not entirely satisfactory in that considerable emphasis was placed upon a number of apparently diagnostic characters which in fact are subject to great variation and intergradation between species (Styron, 1969). The genus, according to Hubricht and Mackin (1949), lacks the sort of singular characters provided for *Asellus* by the structure of the male sexual pleopods (see below), and species recognition is based upon the evaluation of many characters. In the interests of providing some useful indications of the ecological and geographical distributions of *Lirceus* species as described, a summary of relevant data, abstracted mainly from Hubricht and Mackin (1949), has been compiled and is given following the similar summary for *Asellus* compiled from Williams (1970) (see Species List and Distribution below), but no attempt is made to provide a key for their identification here.

The ecological status of *Asellus* in North America is not clear. In most of Europe, *Asellus* (as *A. aquaticus* L.) is characteristically present within given sections of organically polluted rivers. Kolkwitz and Marsson (1909) noted that it is one of the organisms abundant in the so-called α-mesosaprobic polluted zone in particular but also occurs in the β-mesosaprobic zone (the 'α- and β-mesosaprobic zone' proposed by Kolkwitz and Marsson (1909) may be regarded as roughly equivalent to the 'recovery zone' of several American water pollution biologists), and Hynes (1960) noted that *Asellus* is a member (with tubificids and chironomids) of the 'pollution fauna' in the badly polluted zone of rivers affected by organic wastes. Many investigators of North American polluted rivers make no reference to the genus in published accounts of results, whereas others do indicate its occurrence in organically polluted rivers; Bartsch (1948) and Bartsch and Ingram (1959), for example, indicated that it is characteristic of the 'zone of recovery'. In part, some of this ecological uncertainty may be a reflection of the formerly unclear systematic position of surface-living forms.

Because this key to *Asellus* has been prepared for use by biologists concerned with investigating pollution of inland waters, only surface-living forms are discussed. Neither this key nor the more detailed account of Williams (1970) should be regarded as definitive; undoubtedly much remains to be discovered concerning the systematics of North American asellids. It is felt, nevertheless, that the key does deal with those species that are most likely to be encountered.

North American species alone are considered, i.e. species occurring in the United States and Canada. Asellids are known from Mexico (Cole and Minckley, 1968), but are not considered here.

COLLECTING AND PRESERVATION

A variety of methods may be used to collect specimens for qualitative purposes. None requires elaborate apparatus or an involved technique; freshwater asellids are easily-seen, macroscopic animals that are relatively slow-moving, do not swim, and dwell amongst submerged vegetation and bottom detritus. They are not conspicuous burrowers, although they may often occur on the undersurfaces of submerged stones.

The most straightforward method is the direct removal by the investigator of small amounts of submerged vegetation or bottom material either by hand or using a fine-meshed (scrim) dipnet or pondnet followed by the searching of this material for specimens. If asellids occur they may be handled by gripping the middle of their body with a pair of blunt forceps held at right-angles to the long axis of the body. Searching may be facilitated by placing the vegetation or other material to be examined into a white, shallow dish or tray containing water to a depth of about one inch. A tray normally used by the author measures 8 x 10 x 3 inches. If the material is slightly teased apart after being placed in the tray and is then undisturbed for a minute or so, specimens often become conspicuous by their slow movements amongst the material or by their movement from the material towards clear areas of water in the tray. Such specimens may also be removed by forceps, but a better, less damaging method is to suck them gently with some water into a glass tube (diameter about 3/8 inch) in which suction is maintained by a rubber bulb attached to one end. A little practice on the part of the operator is required with this tube method of handling specimens for satisfactory performance. Asellids may also often be collected by removal of submerged stones and the examination of their lower surfaces.

Specimens are best killed and preserved by directly placing them in 70-80% ethyl alcohol. Transference to fresh alcohol after a few days is recommended. Care should be exercised to ensure that crowding of preserved specimens does not occur, and that tubes are adequately labelled. The maintenance of live specimens is not required for species identification.

It should be stressed that reasonably large collections are necessary for adequate systematic examination since species identification (for both *Asellus* and *Lirceus*) is based on adult males only, and more than one species may occur in the same collection. *Lirceus* and *Asellus* may also occur together. It is suggested that 25 specimens be regarded as the minimal adequate number for one collection, although, of course, smaller collections will often be useful also.

IDENTIFICATION

For generic separation of *Lirceus* and *Asellus* and for species identification of *Asellus* it will be necessary in using this publication to be familiar with the conformation of and the terminology applied to at least certain parts of the external structure of asellids. For confirmation of species identity by reference to the original description or to a complete description given elsewhere, a similar familiarity will be required with regard to most of the remaining body parts. Before discussing the actual technique of specimen examination, it is appropriate therefore to describe briefly the morphology of a typical species. *Asellus communis* has been selected for this purpose.

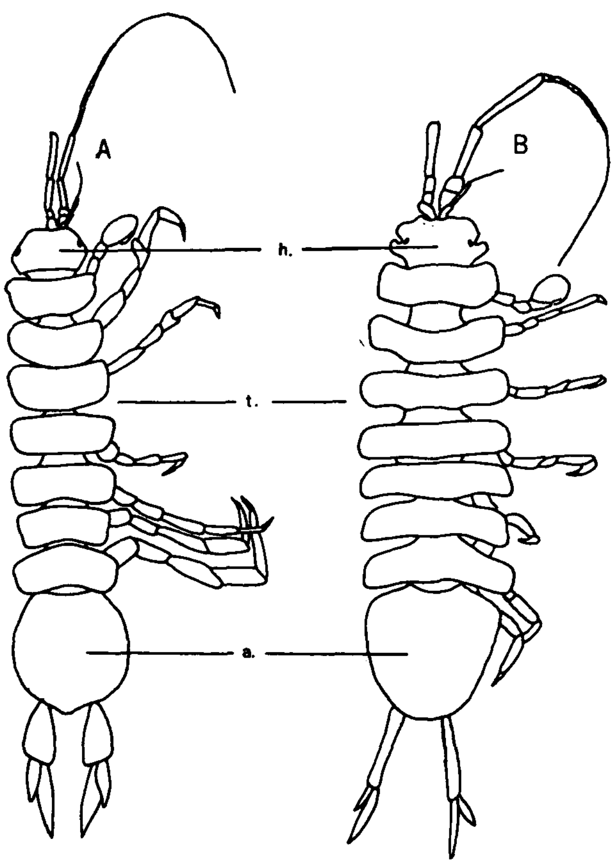


Fig. 1. A, dorsal view of male *Asellus communis*; B, dorsal view of male *Lirceus* sp. Drawn from preserved specimens. Original. a.=abdomen, h.=head, t.=thorax.

There are three major body regions, the head, thorax, and abdomen (Fig. 1). The head and abdomen appear unsegmented, whereas the thorax is divided into seven segments. Each region bears a number of appendages projecting either anteriorly, posteriorly, ventrally or laterally.

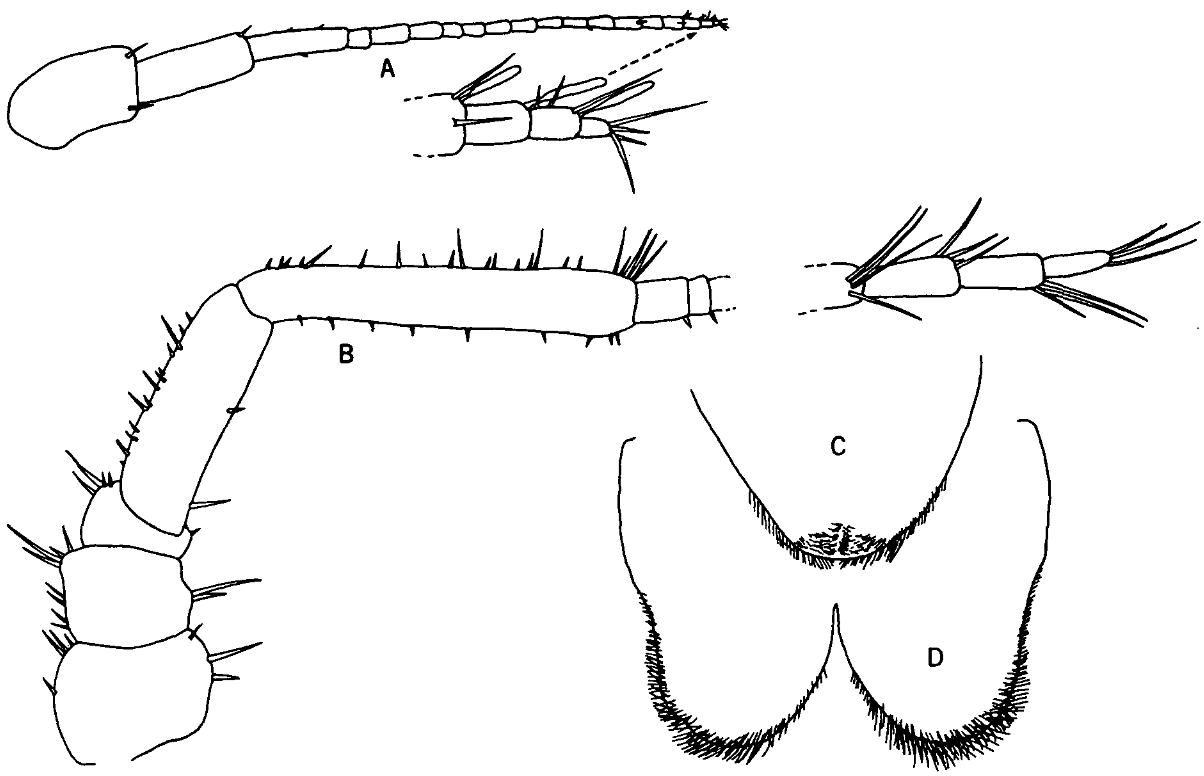


Fig. 2. *A. communis:* A, first antenna; B, second antenna; C, upper lip; D, lower lip. From Williams (1970).

Anteriorly, the head bears a pair of short antennae (first antennae or antennules) and a pair of much longer ones (second antennae or, simply, antennae) (Fig. 2A, B). Ventrally the head bears a mouth which has an upper (or anterior) lip or flap and a bilobed, lower (or posterior) lip (Fig. 2C, D). Posterior to the mouth is a paired series of small appendages used in feeding; from front to back these are respectively the mandibles, first maxillae (or maxillules), second maxillae (or, simply, maxillae), and maxillipeds (Fig. 3A-F). In addition the head has a pair of small eyes; these occur dorsally, one on each side (Figs 1A, 8B).

Each segment of the thorax is dorsoventrally flattened and bears laterally a leg or peraeopod (pereiopod or pereopod); in all there are seven pairs (Fig. 1A). There are some differences in structure between each pair of legs, but these are not great, and only the structure of the first pair of legs of adult males is distinctly different in that the two most distal leg segments are expanded to form a claw-like apparatus (Figs 4A,B; 5A-F). The palm of this usually bears near its midpoint a prominent triangular projection and proximally a few tooth-like setae (Fig. 4A). Each leg consists of six apparent segments, termed respectively the dactylus, propodus, carpus, merus, ischium and basis of which the dactylus is the most distal. A seventh leg segment, the

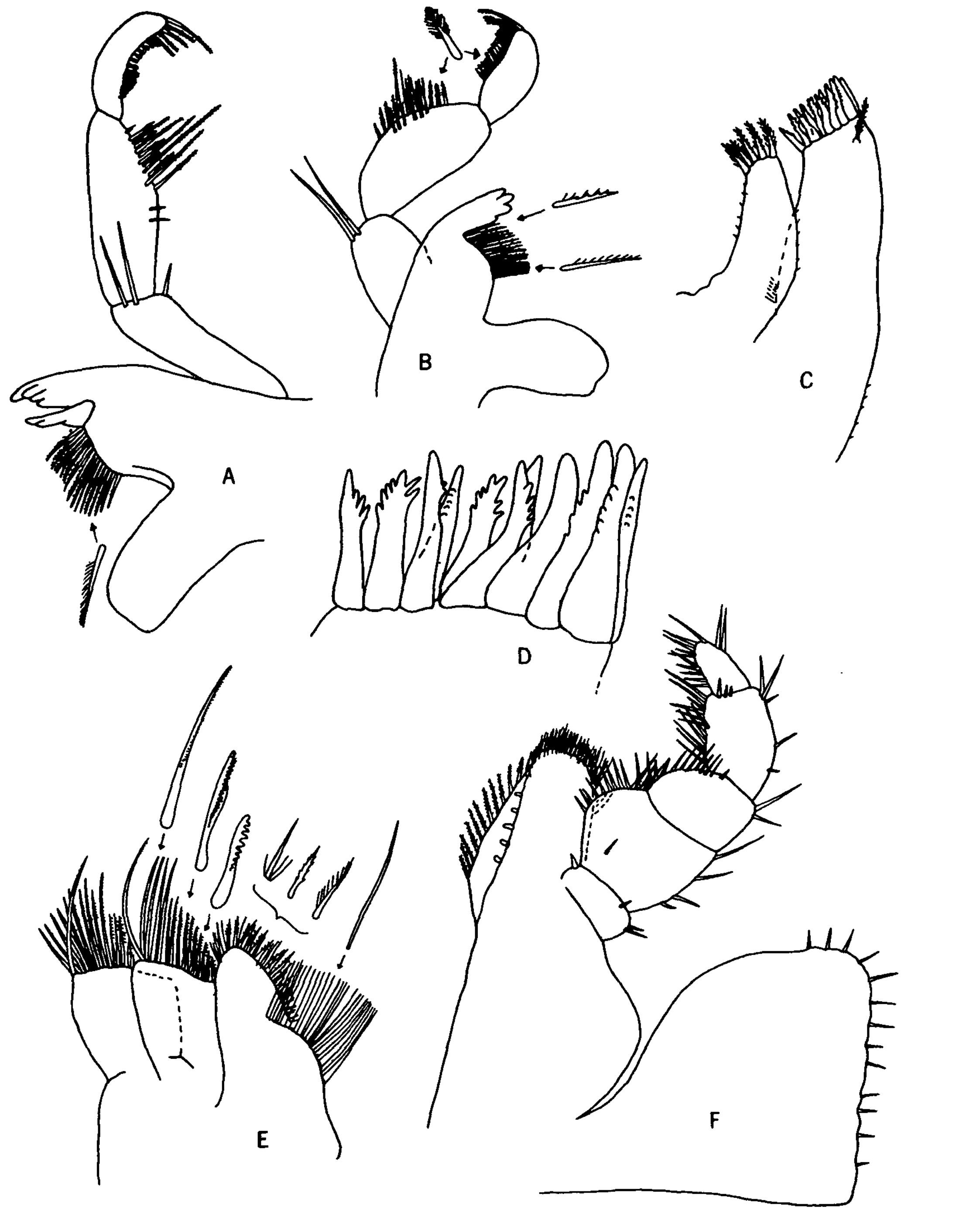


Fig. 3. *A. communis:* A, left mandible; B, right mandible; C, first maxilla; D, distal margin of outer plate of first maxilla; E, second maxilla (dorsal surface); F, maxilliped. From Williams (1970).

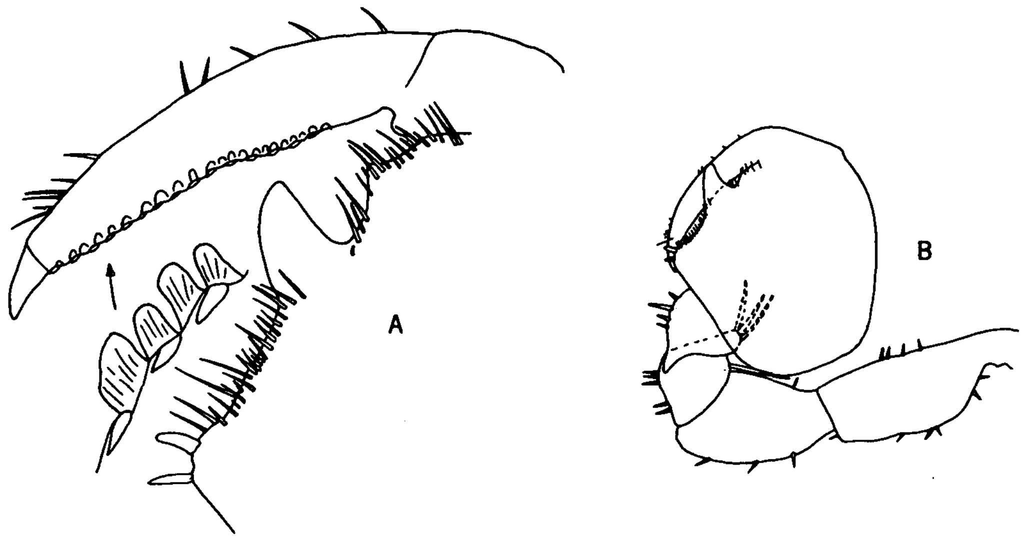


Fig. 4. *A. communis:* A, dactylus and palm of first peraeopod; B, first peraeopod. From Williams (1970).

coxa, is not distinct from the thorax. Dorsally, the thorax is covered by a tergal plate, which in the second to seventh segments is expanded to a small lobe at each anterolateral angle. Breeding females bear ventrally a series of flaps, oostegites, which arise from near the inside of the base of the anterior legs and form a brood-pouch or marsupium. In non-breeding females, their place is taken by small, club-shaped structures. In males, a pair of tube-like penes arise from the posterior, ventral margin of the last thoracic segment; the penes project backwards.

The abdomen is conspicuously dorsoventrally flattened. In males, five pairs of pleopods are borne ventrally, of which the anterior two pairs are small and serve a sexual function (Fig. 6A, B). The remaining pleopod pairs (3-5, Fig. 7A-C) are large, plate-like, and serve a respiratory function; each of these pleopods consists of a larger, more robust and variously setose lower plate (exopod), and a smaller, fragile, non-setose upper (or inner) plate (endopod). In females, only four pairs of pleopods occur (the true first pair are always absent) of which the most anterior pair consists of small and simple triangular plates, whilst the remaining three pairs are similar to those in males.

Of greatest importance in the identification of *Asellus* species is the structure of the first and second male pleopods, and of critical importance is the conformation and shape of the tip of the endopod of the second pleopod; especially marked variation between species is displayed in the structure of the endopod tip. It is for this reason that these appendages are discussed further below firstly for *A. communis* in particular, and secondly, with respect to the conformation of the tip of the endopod of the second pleopod alone, for all North American species of *Asellus* in general.

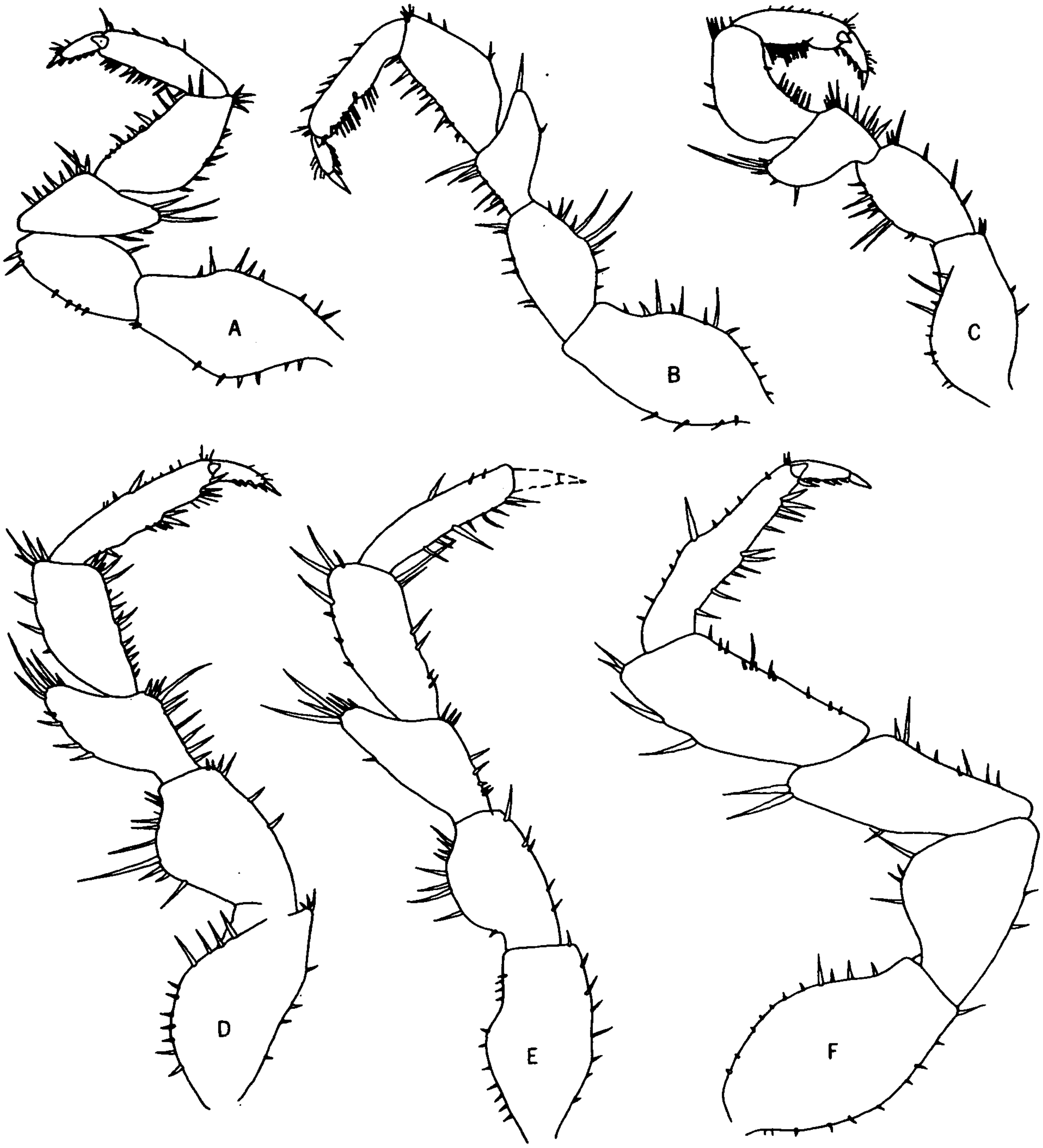


Fig. 5. *A. communis*, peraeopods: A, second; B, third; C, fourth; D, fifth; E, sixth; F, seventh. From Williams (1970).

The first pleopod of the male (Fig. 6A) consists of two segments, a basal sympod and a distal segment. The second pleopod (Fig. 6B) consists of a large sympod bearing distally a two-segmented exopod (outermost structure) and an unsegmented endopod (innermost structure) (Fig. 6C). The endopod has two laterally projecting lobes basally, inner and outer apophyses.

From near the distal tip of the endopod (Fig. 6D, E) projects a tube-like cannula, whilst the distal edge of the endopod itself gives rise to a rounded lobe, the caudal process. This conformation of endopod tip is unique to *A. communis*. It, and that for other North American species of

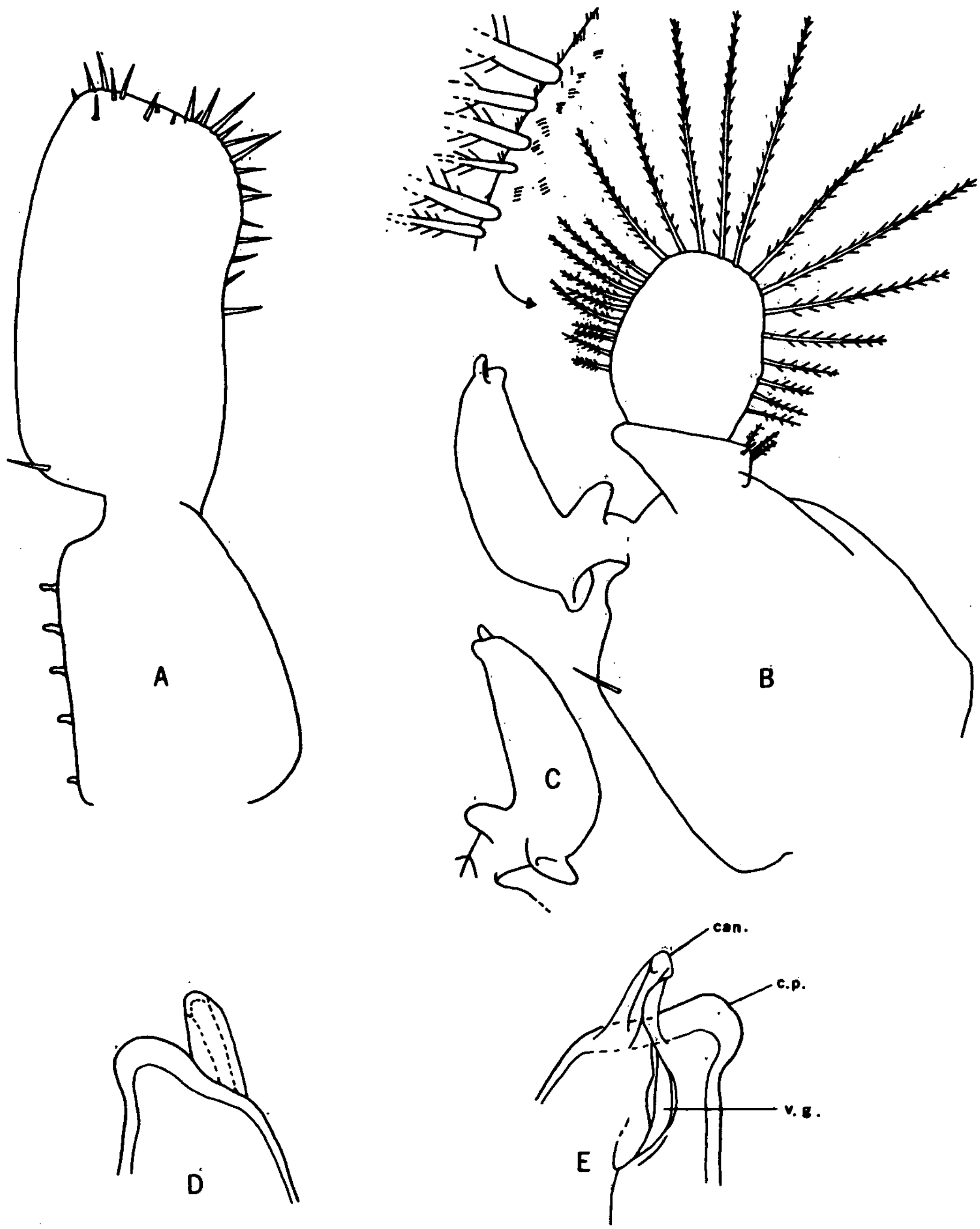


Fig. 6. *A. communis:* A, first pleopod; B, second pleopod; C, dorsal surface of endopod of second pleopod; D,E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod. (After Williams, 1970).
can.=cannula, c.p.=caudal process, v.g.=ventral groove.

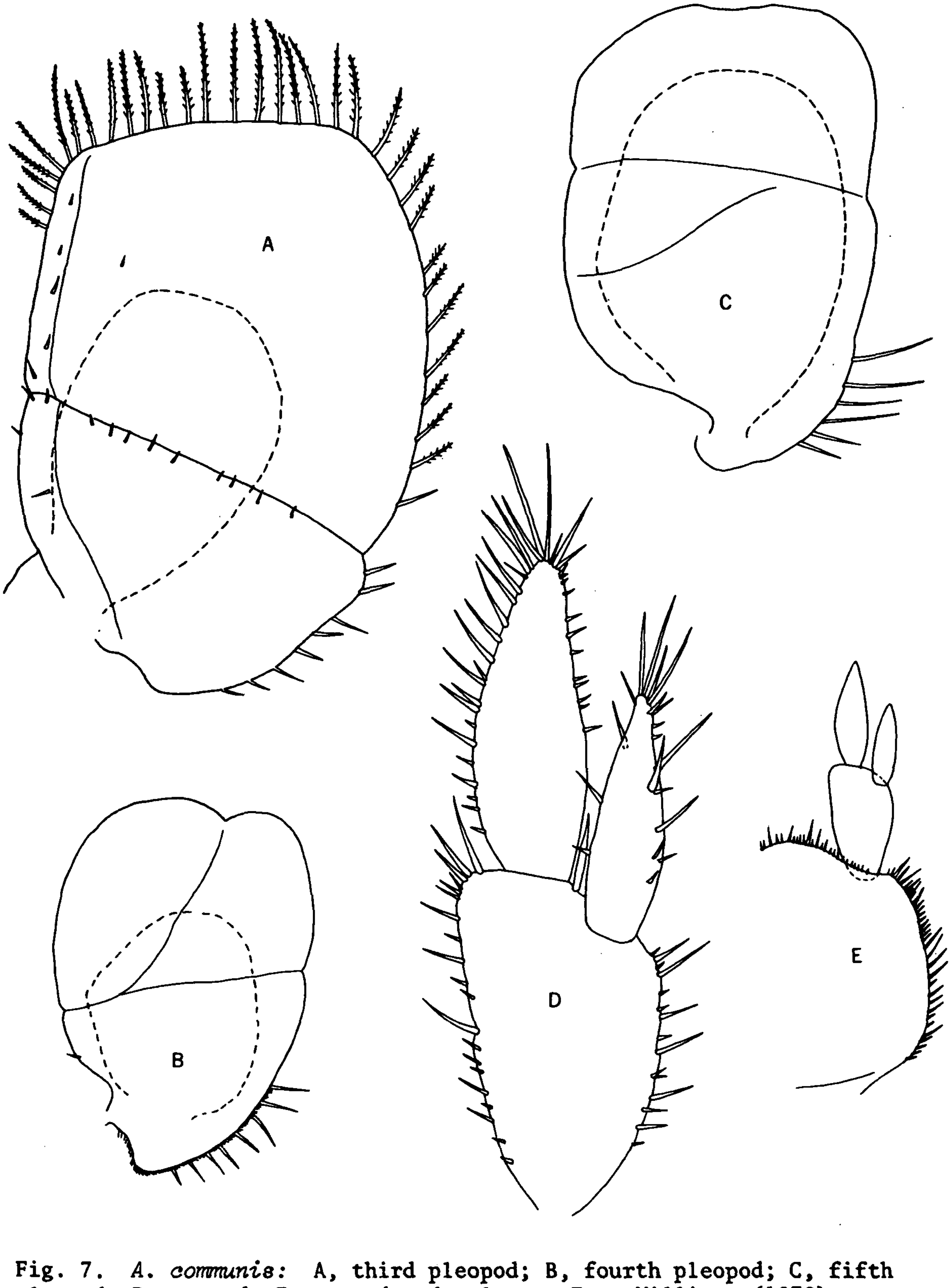


Fig. 7. *A. communis:* A, third pleopod; B, fourth pleopod; C, fifth pleopod; D, uropod; E, uropod and telson. From Williams (1970).

Asellus, appears to be derivable from a structure consisting in principle of a terminal ventral groove associated with which are four terminal elements: a mesial process arising from the medial edge of the ventral groove; a cannula, essentially a tubular prolongation of the ventral groove; a lateral process arising from the lateral edge of the groove; and a terminal caudal process. Loss or modification of these elements, it has been suggested, can produce the conformation unique for each species of *Asellus*.

A final pair of abdominal appendages project backwards from the posterior border of the abdomen; these appendages are the uropods. Each (Fig. 7D) consists of a basal segment, the peduncle, and two distal segments or rami, an inner one, the endopod, and an outer one, the exopod. The upper surface of the region referred to here as the abdomen in effect constitutes the telson, also referred to as the pleotelson (Fig. 7E).

EXAMINATION TECHNIQUE. A stereoscopic and a compound microscope, a pair of fine forceps, a mounted needle, a petri-dish (or similar container) and microscope slides and coverslips are equipment needed for species identification. Preliminary examination and dissection should be made using the stereoscopic microscope with the specimens immersed in 70-80% ethyl alcohol and illuminated by reflected light against a dark background. Further identification is carried out by removing appropriate appendages or body parts, mounting these on a microscope slide in a small amount of the alcohol from which they were withdrawn, and examining by transmitted or reflected light as appropriate. Such preparations are temporary; more permanent ones may be made using one of several mounting reagents now commercially available which do not require passage of specimen material through a series of other reagents. The author uses "Euparol" (George Gurr Ltd., U.K.). Readers are warned, however, that many such mounting reagents also include clearing agents and if their action is too severe distortion and contraction of mounted material (particularly of the endopod tip of the second pleopod of male *Asellus* specimens) may occur. It is important that this does not happen. Readers are also warned that endopod tips of the second pleopod of male *Asellus* specimens should be viewed in a variety of positions so that a better appreciation of the arrangement of terminal parts is gained.

SECTION II

SPECIES LIST AND DISTRIBUTION

It is stressed that our knowledge of species distributions is still incomplete so that the notes below on this subject are to be regarded as summaries of known distributions not actual distributions.

Genus *Asellus*

Asellus attenuatus Richardson, 1900. Known only from one locality, Dismal Swamp, Virginia (*see* Richardson, 1901).

Asellus brevicauda brevicauda Forbes, 1876. Springs and spring-fed streams in large but relatively restricted area of east-central United States: Arkansas, Illinois, Kentucky, Missouri.

Asellus brevicauda bivittatus Walker, 1961. Known only from one locality, Doe Run, a spring-fed creek in Kentucky.

Asellus communis Say, 1818. Creeks, rivers, ponds, lakes, reservoirs, occasionally in swamps. Not present in the Great Lakes. Mainly distributed in northeastern United States and southeastern Canada, but has also been recorded from Colorado and Washington, Complete list of States and Provinces: Colorado, Maine, Maryland, Massachusetts, New Jersey, Pennsylvania, Vermont, Washington, West Virginia; Nova Scotia, Ontario.

Asellus dentadactylus Mackin and Hubricht, 1938. Small creeks in Arkansas and Louisiana.

Asellus forbesi Williams, 1970. Typically in temporary ponds, flood pools, and sloughs, but also in marshes, small creeks, and occasionally lakes. Has been collected from Lake Huron at a depth of 15 meters. Distributed over very large area of east-central United States and in southern Ontario. Complete list of States and Provinces: District of Columbia, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, North Carolina, Ohio, South Carolina, Virginia, West Virginia, Ontario.

Asellus intermedius Forbes, 1876. Typically in running waters (creeks, streams and rivers), but also in springs, ditches, ponds, lakes. Large area of east-central United States and southern Ontario: Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, Wisconsin; Ontario.

Asellus kenki Bowman, 1967. Springs and spring-fed creeks (not in large streams and ponds) in small area near Washington, D. C.: District of Columbia, Maryland, Pennsylvania, Virginia.

Asellus laticaudatus Williams, 1970. Small creeks and ponds in southeastern United States: Kentucky, Louisiana.

Asellus montanus Mackin and Hubricht, 1938. Creeks, streams, sloughs in Arkansas and Oklahoma.

Asellus nodulus Williams, 1970. Swamps, roadside ditches, streams, and spring outlets in Maryland.

Asellus obtusus Williams, 1970. Swamps, roadside ditches, temporary ponds, rivers, small streams in small region of southeastern United States: Florida, Georgia, Louisiana.

Asellus occidentalis Williams, 1970. Spring-brooks, streams, rivers, marshy edges of lakes in far northwestern United States and extreme southwestern Canada: Oregon, Washington; British Columbia.

Asellus racovitzai racovitzai Williams, 1970. Creeks, rivers, ponds, swamps, small lakes, and great Lakes down to 42 meters. Mainly distributed in northeastern United States and southeastern Canada, but has also been recorded from Washington. Complete list of States and Procinces: District of Columbia, Indiana, Maryland, Massachusetts, Michigan, Vermont, Washington; Ontario, Quebec. It is the dominant Greât Lakes species except for Lake Michigan from where it is still unrecorded (*see* Racovitza, 1920)

Asellus racovitzai australis Williams, 1970. Creeks and rivers in southeastern United States: Florida, Georgia.

Asellus scrupulosus Williams, 1970. Vernal and woodland pools in West Virginia.

Genus *Lirceus*

Lirceus alabamae Hubricht and Mackin, 1949. Seeps and springs in Alabama.

Lirceus bicuspidatus Hubricht and Mackin, 1949. Springs, seeps, creeks, and streams in Arkansas.

Lirceus bidentatus Hubricht and Mackin, 1949. Known only from a seep in Arkansas.

Lirceus brachyurus (Harger, 1876). Springs and small streams of Atlantic drainage from northeastern Pennsylvania to northern Virginia: Pennsylvania, Virginia.

Lirceus fontinalis Rafinesque, 1820. Typically in springs but also in drain outlets, seeps and streams: Georgia, Illinois, Indiana, Kentucky, Ohio, Tennessee.

Lirceus garmani Hubricht and Mackin, 1949. Springs, seeps, creeks, streams (sometimes temporary) and ponds (also sometimes temporary) in Arkansas, Kansas, Missouri, Oklahoma.

Lirceus hargeri Hubricht and Mackin, 1949. Springs in Tennessee and Virginia.

Lirceus hoppinae hoppinae (Faxon, 1889). Springs in Missouri (*see* Garman, 1889).

Lirceus hoppinae ozarkensis Hubricht and Mackin, 1949. Springs and sometimes streams in Missouri and northern Arkansas.

Lirceus hoppinae ouachitaensis (Mackin and Hubricht, 1938). River tributaries in Oklahoma.

Lirceus lineatus (Say, 1818). Rivers, creeks, sloughs, swamps, lakes including Great Lakes. Distributed in Great Lakes region and southeastern United States from Virginia to Florida and Alabama. Complete list of States and Provinces: Alabama, Florida, Georgia, Illinois, Indiana, Michigan, New York, South Carolina, Tennessee, Virginia; Ontario.

Lirceus louisianae (Mackin and Hubricht, 1938). Spring-fed marshes, temporary pools, sloughs, roadside ditches, small streams, seeps: Arkansas, Illinois, Louisiana, Missouri.

Lirceus megapodus Hubricht and Mackin, 1949. Springs in Missouri.

Lirceus richardsonae Hubricht and Mackin, 1949. Known only from a drain outlet in Ohio.

Lirceus trilobus Hubricht and Mackin, 1949. Known only from woodland pools in Oklahoma.

SECTION III

KEY TO GENERA OF NORTH AMERICAN FRESHWATER ASELLIDAE

1 Lateral margin of head produced to form thin plate covering or overhanging base of mandible, this plate frequently but not always incised (Fig. 8A). Anterior margin of head with pointed median protuberance (carina) between bases of antennules (Fig. 8A). Distal segment of exopod of pleopod 3 (outer gill operculum) approximately hemispherical in shape, with division between it and proximal segment running obliquely backwards from inner distal angle (Fig. 9A): *Lirceus* Rafinesque (species not identified here; see Introduction)

Lateral margin of head not produced to cover or overhang base of mandible (Fig. 8B). Anterior margin of head without a median protuberance between bases of antennules (Fig. 8B). Distal segment of exopod of pleopod 3 (outer gill operculum) sub-quadrangular in shape, division between it and proximal segment running approximately at right-angles to long axis of specimen and commencing well anterior to inner distal angle of appendage (Fig. 9B): *Asellus* St. Hilaire (page 19)

Fig. 8. Dorsal view of head: A, *Lirceus* sp.; B, *Asellus* sp. Original ca.=carina, e.=eye.

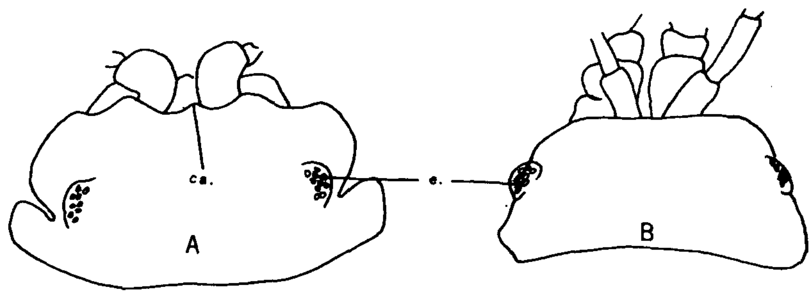
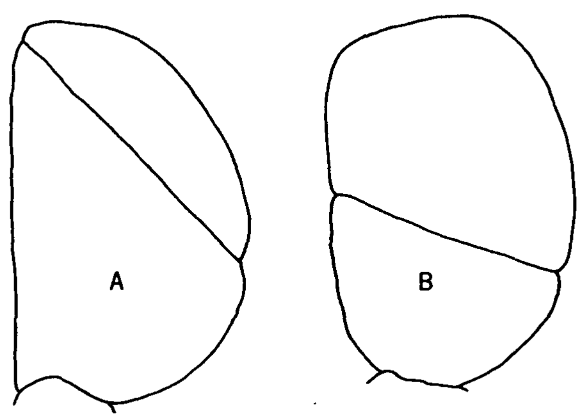


Fig. 9. Third pleopod: A, *Lirceus* sp.; B, *Asellus* sp. Original.



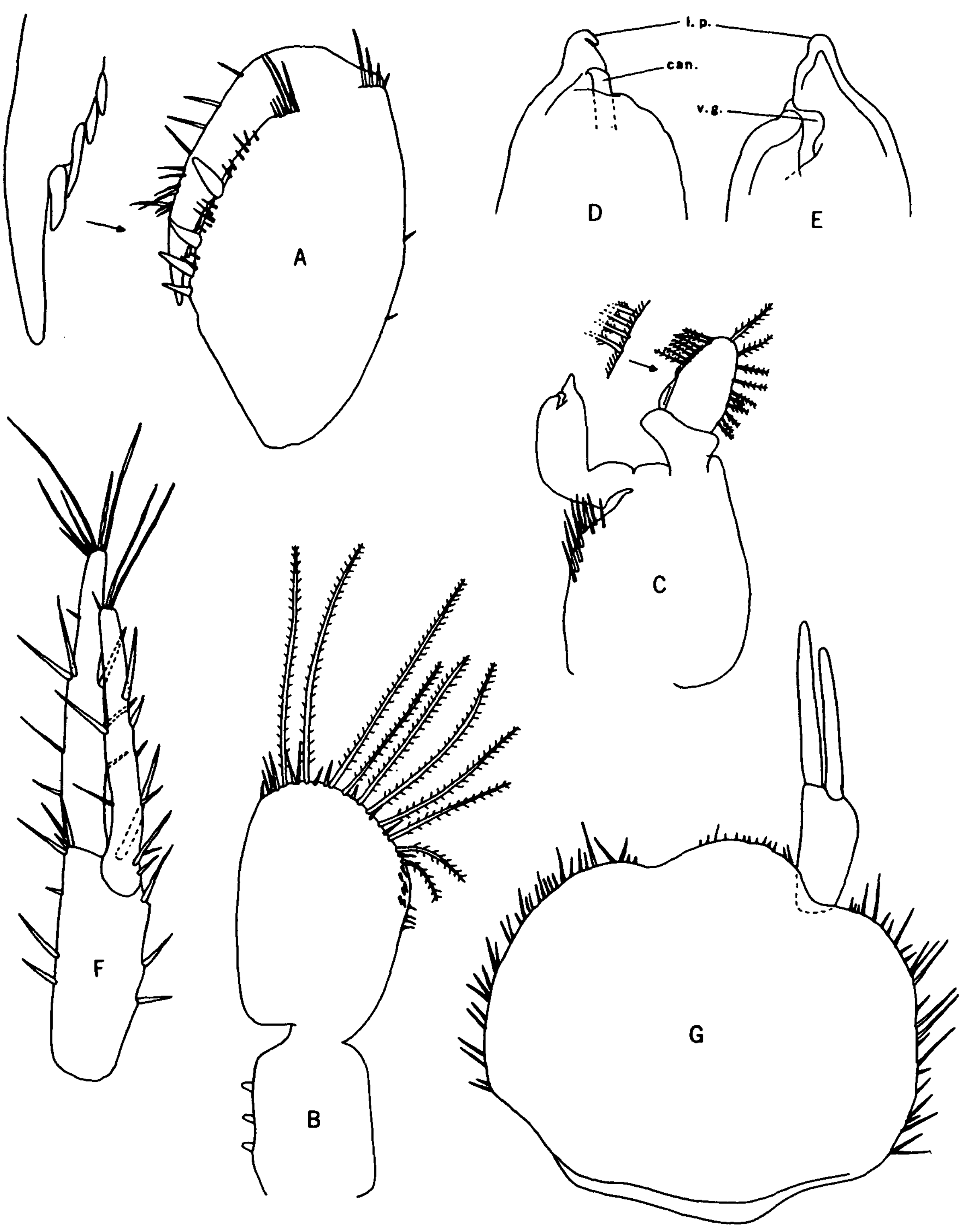


Fig. 10. *A. occidentalis*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod; G, uropod and telson. (After Williams, 1970).
can.= cannula, l.p.= lateral process, v.g.= ventral groove.

SECTION IV

KEY TO NORTH AMERICAN SURFACE-LIVING SPECIES OF *ASELLUS*

The following key is of use only for adult male specimens; as indicated in the text above, it is the males which in *Asellus* provide the diagnostic characters for the species separation. Females cannot be identified at present. In the key, the terms mesial process, lateral process, caudal process, ventral groove, and cannula refer to structures at the tip of the endopod of the second pleopod. All drawings of the first and second pleopods, unless contraindicated, are of right pleopods. With respect to the surface of these, ventral=anterior, and dorsal=posterior. All principal distinguishing characters have been used in compiling the key, and are illustrated in the accompanying figures (no direct reference may be made to such characters in the final part of the couplet for each species). In certain cases, to aid identification some quantitative data are given in tabular form.

1 Palm of propodus of peraeopod 1 lacking triangular process near midpoint, but with 3-5 teeth-like spines variously arranged (Fig. 10A). Pleopod 1 distinctly longer than pleopod 2, distal segment with numerous long plumose setae (Fig. 10B). Pleopod 2 with mesial and caudal processes not developed, but lateral process large, projecting beyond cannula, and distally recurved (Figs 10D, E, 11A-E); endopod shape and relative proportions of segments as in Fig. 10C. Both exopod and endopod of uropod longer than peduncle (Fig. 10F, G): *A. occidentalis*

Palm of propodus of peraeopod 1 usually (not always) with both a large triangular process near midpoint and some teeth-like spines variously arranged. Pleopod 1 either longer than pleopod 2 and distal segment with numerous long plumose setae, or shorter to subequal in length to pleopod 2 and lacking distal plumose setae. Lateral process of pleopod 2 either absent or developed in conjunction with mesial process (i. e. not as shown in Figs 10D, E, 11A-H); endopod shape and relative proportions of segments more or less dissimilar to those shown in Fig. 10C. Exopod of uropod typically shorter than peduncle, endopod usually subequal in length to peduncle (but sometimes longer) 2

2(1) Pleopod 1 usually subequal in length to pleopod 2 or distinctly shorter, distal segment subovate to subrectangular without long plumose setae on distal margin but with few to numerous short simple setae. Pleopod 2 with prominent cannula, often wide, never hidden ventrally by lateral or mesial processes 3

Pleopod 1 usually distinctly longer than pleopod 2, distal segment usually subovate, often curved outward, and with few to numerous long plumose setae on distal margin. Pleopod 2 with small, narrow cannula sometimes hidden ventrally by lateral or mesial processes 10

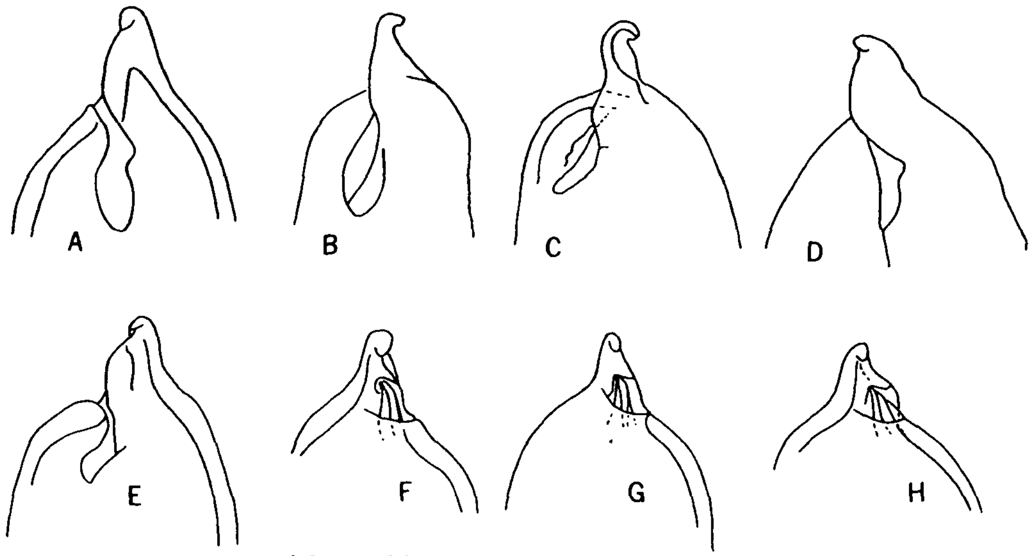


Fig. 11. *A. occidentalis.* Variation in morphology of tip of endopod of second pleopod. A-E, ventral views; F-H, dorsal views. From Williams (1970).

3(2) Pleopod 2 with neither mesial nor caudal processes developed, only cannula projects distally from endopod tip (Figs 12D, E, 13A-F); dorsal surface of distal end of endopod with numerous minute comb-like structures (Fig. 12D); endopod shape and proportion of segments as in Fig. 12C. Both rami of uropod always flat, lanceolate and broad (Fig. 12F, G): *A. laticaudatus*

Caudal process of pleopod 2 always more or less developed, mesial process either developed or not, cannula never only process to project distally from endopod tip; dorsal surface of distal end of endopod usually lacking minute comb-like structure (if present, these extend on to caudal process); endopod shape and proportions of segments more or less dissimilar to drawings of Fig. 12C. Rami of uropod either flat, lanceolate and broad or linear and narrow 4

4(3) Mesial process of pleopod 2 scarcely or not present 5
Mesial process of pleopod 2 present and well-developed 6

5(4) Inner and outer basal apophyses of endopod of pleopod 2 distinct (Fig. 6B, C); caudal process usually broadly rounded, cannula long and narrow (Figs 6D, E, 14A-M); shape of endopod and proportions of segments as in Fig. 6B: *A. communis*

Inner basal angle of endopod of pleopod 2 obtuse, sharply angled, or produced into small, acutely pointed apophysis, outer basal apophysis not distinct (Fig. 15C); caudal process often with acutely pointed apex, cannula short and wide (Figs 15D, 16A-H); shape of endopod and proportions of segments as in Fig. 15C: *A. intermedius*

6(4) Cannula of pleopod 2 long and narrow or triangular 7
Cannula of pleopod 2 relatively short and wide 9

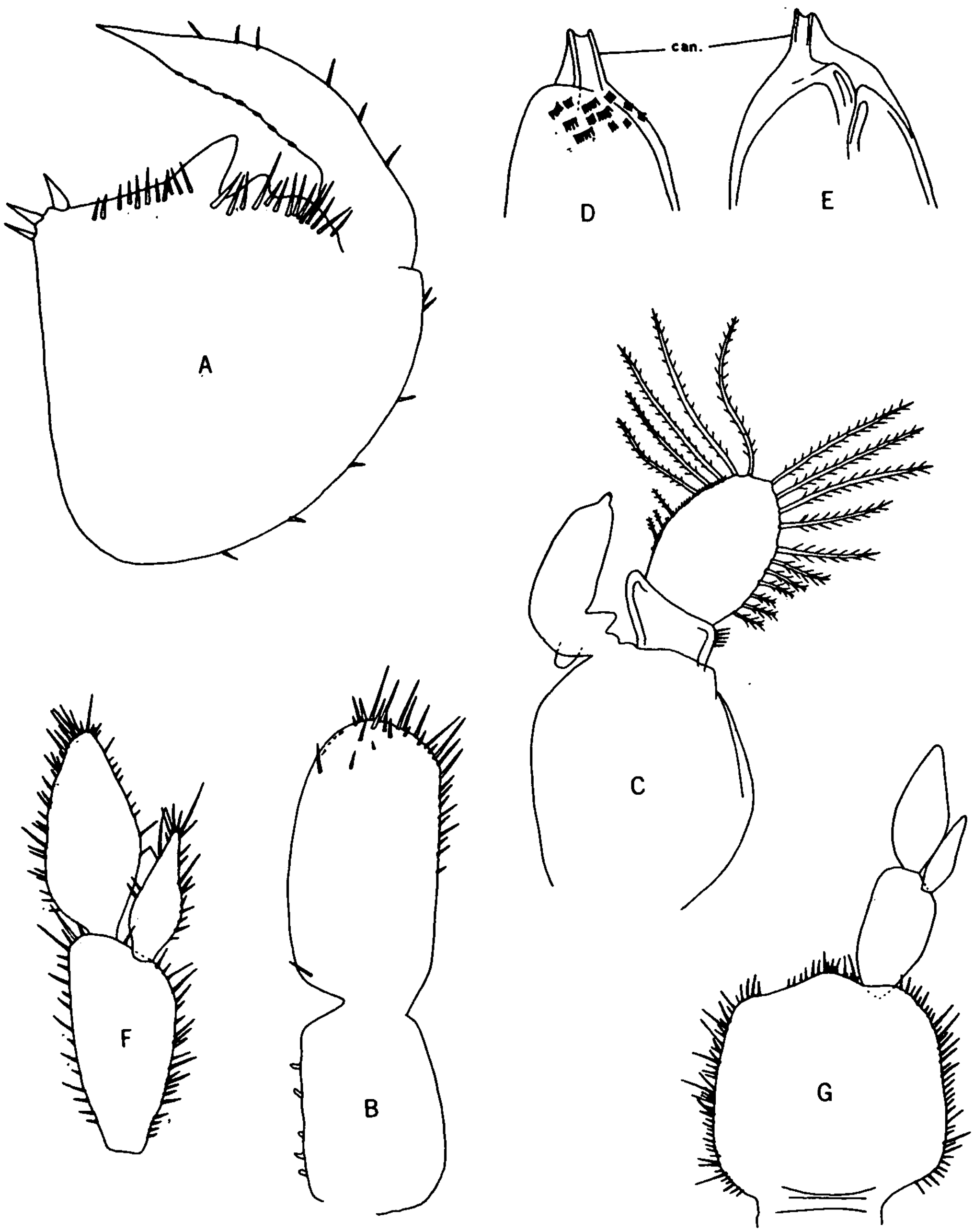


Fig. 12. *A. laticaudatus*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of endopod of second pleopod; F, uropod; G, uropod and telson. (After Williams, 1970).
can.= cannula.

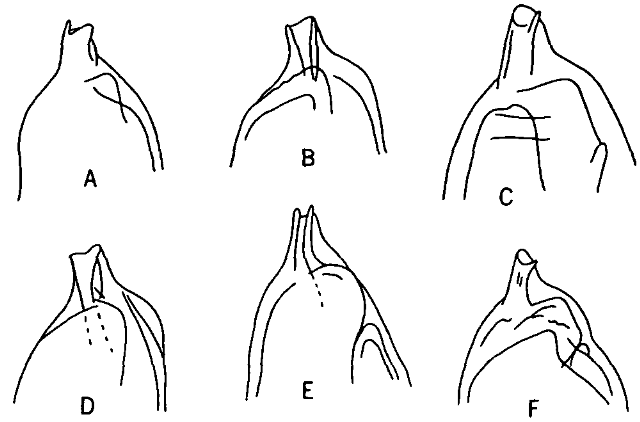


Fig. 13. *A. laticaudatus*. Variation in morphology of tip of endopod of second pleopod. A-F, ventral views. From Williams (1970).

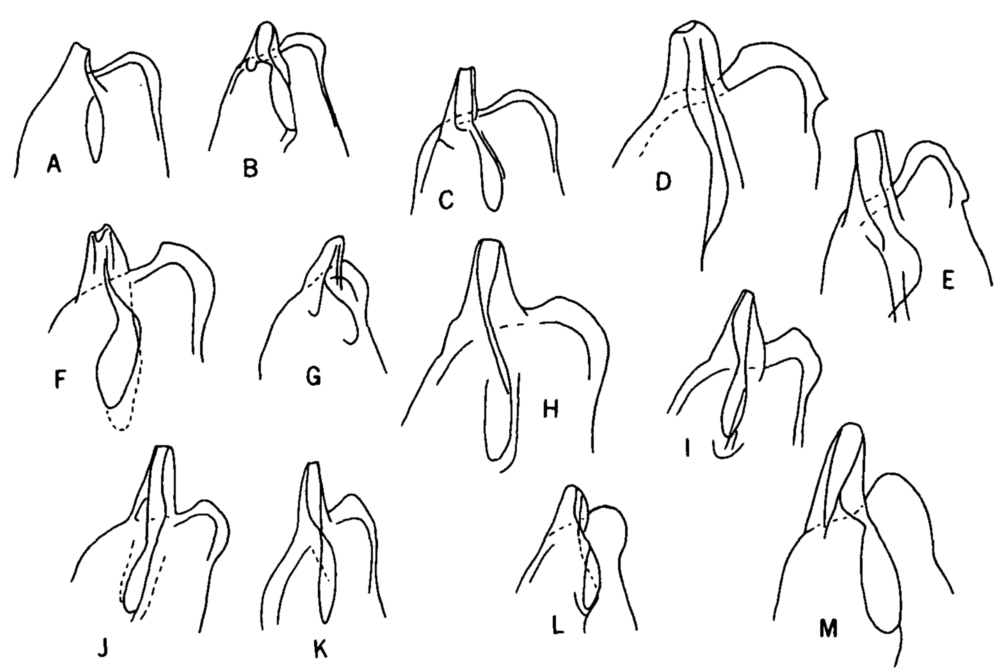


Fig. 14. *A. communis*. Variation in morphology of tip of endopod of second pleopod. A-M, ventral views; A-K, specimens from eastern States and southeastern Canada; L, specimen from Washington; M, specimen from Colorado. From Williams (1970).

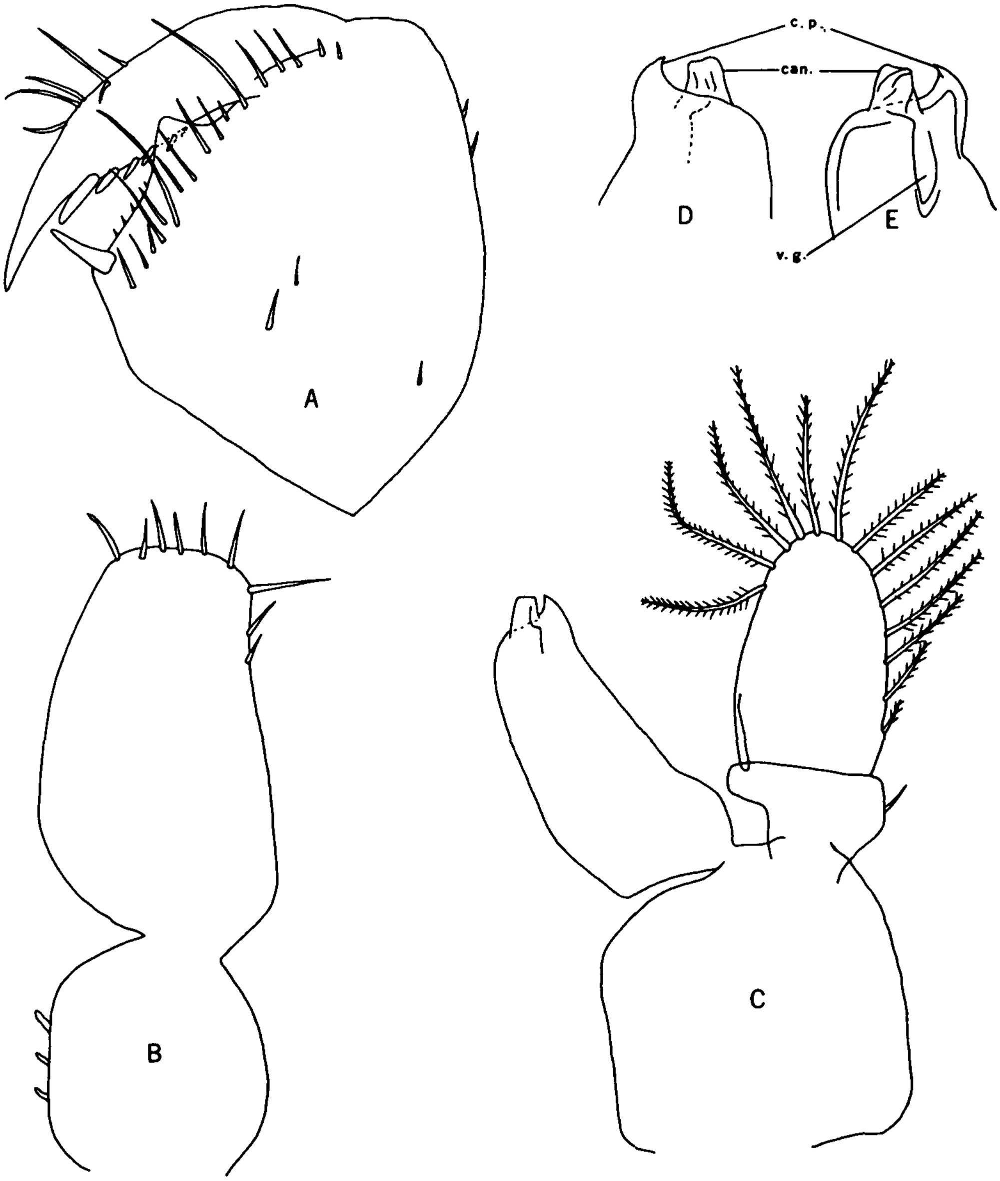


Fig. 15. *A. intermedius*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod. (After Williams, 1970).
can.= cannula, c.p.= caudal process, v.g.= ventral groove.

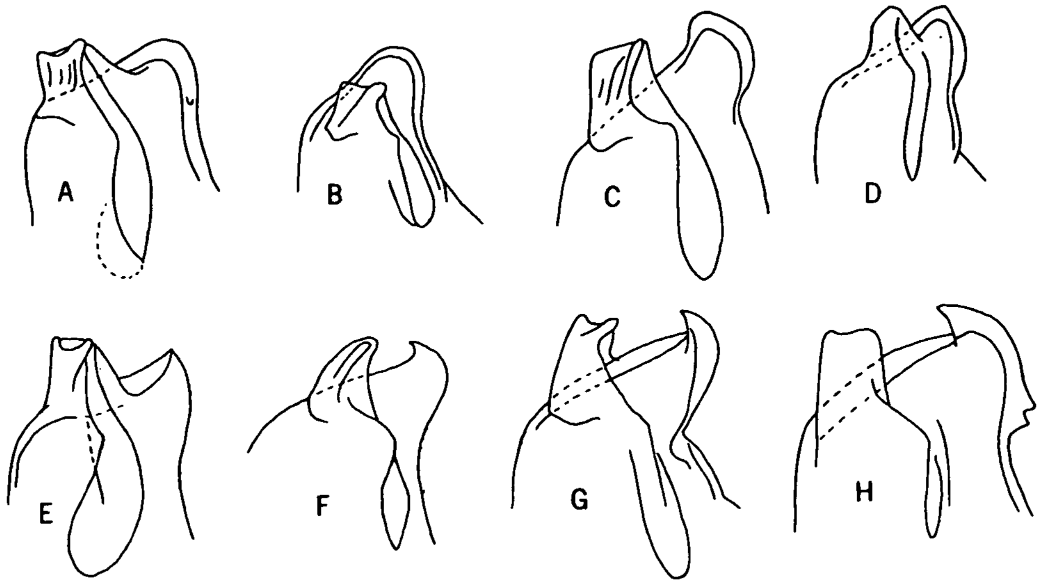


Fig. 16. *A. intermedius.* Variation in morphology of tip of endopod of second pleopod. A-H, ventral views. From Williams (1970).

7(6) Antenna 2 slightly longer than body. Pleopod 1 distinctly shorter than pleopod 2, division of distal and proximal segments incomplete (Fig. 17B). Caudal process of pleopod 2 rounded, not well-developed (but clearly present), and lacking associated hooks and setae; cannula and subequal mesial process extending beyond caudal process (Fig. 17D, E); shape of endopod and proportions of segments as in Fig. 17C. Rami of uropod linear, narrow and subequal in length to each other (endopod only slightly longer) (Fig. 17F): *A. attenuatus*

Antenna 2 usually shorter than body but sometimes subequal. Pleopod 1 subequal in length to or slightly longer than pleopod 2, division between distal and proximal segments more or less complete (Figs 18B, 20A-H, 21B). Caudal process of pleopod 2 distinctly developed, large, terminating in prominent apex, usually with several fine comb-like structures on dorsal surface and some lateral setose processes; cannula and mesial process usually not extending distally beyond caudal process (Figs 18D, E, 19A-J, 21D, E, 22A-F); shape of endopod and proportions of segments more or less dissimilar to Fig. 17C. At least endopod of uropod lanceolate, distinctly longer than exopod (Figs 18F, 21F) .... *A. racovitzai* 8

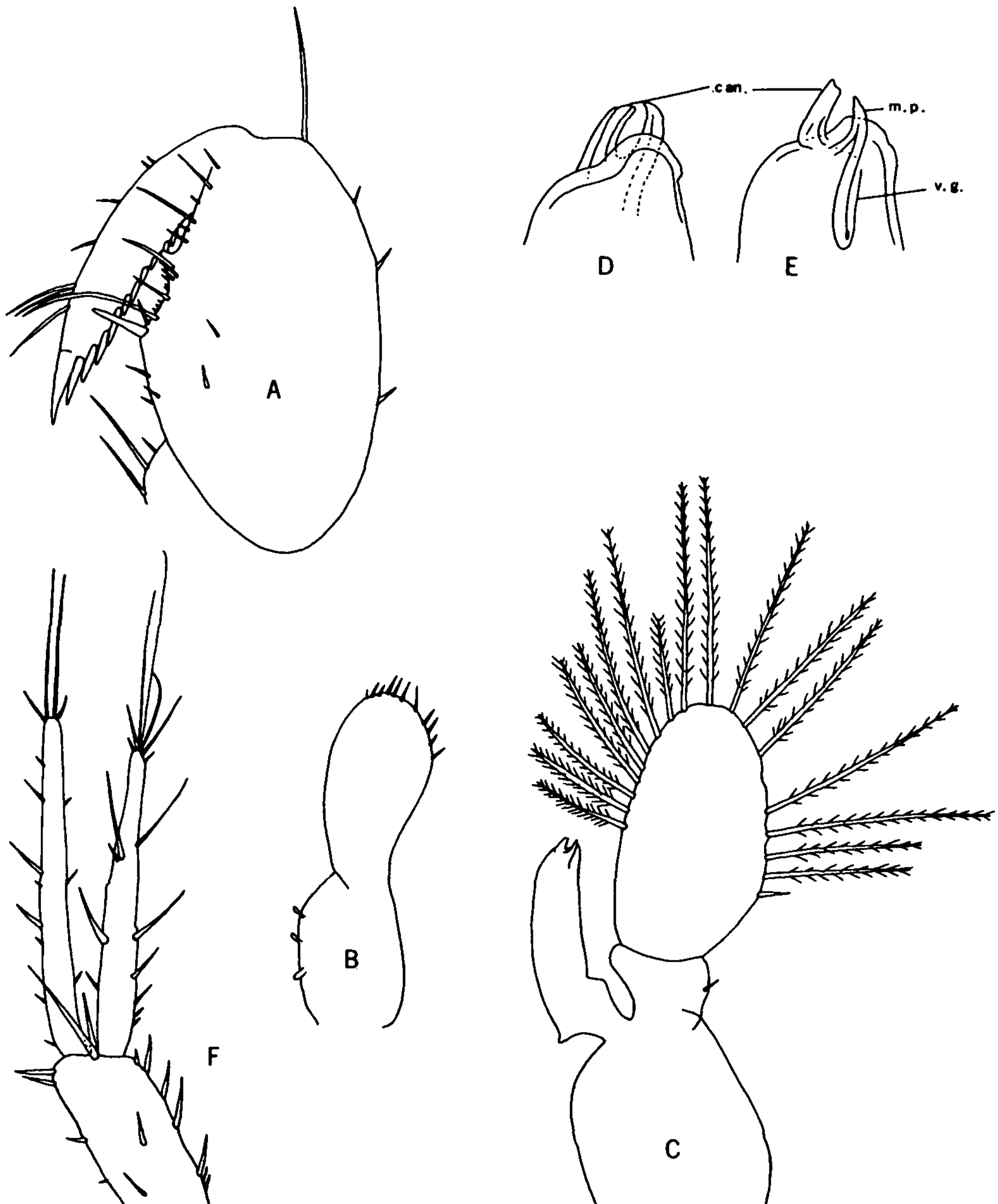


Fig. 17. *A. attenuatus*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of second pleopod; F, uropod. (After Williams, 1970).
can.= cannula, m.p.= mesial process, v.g.= ventral groove.

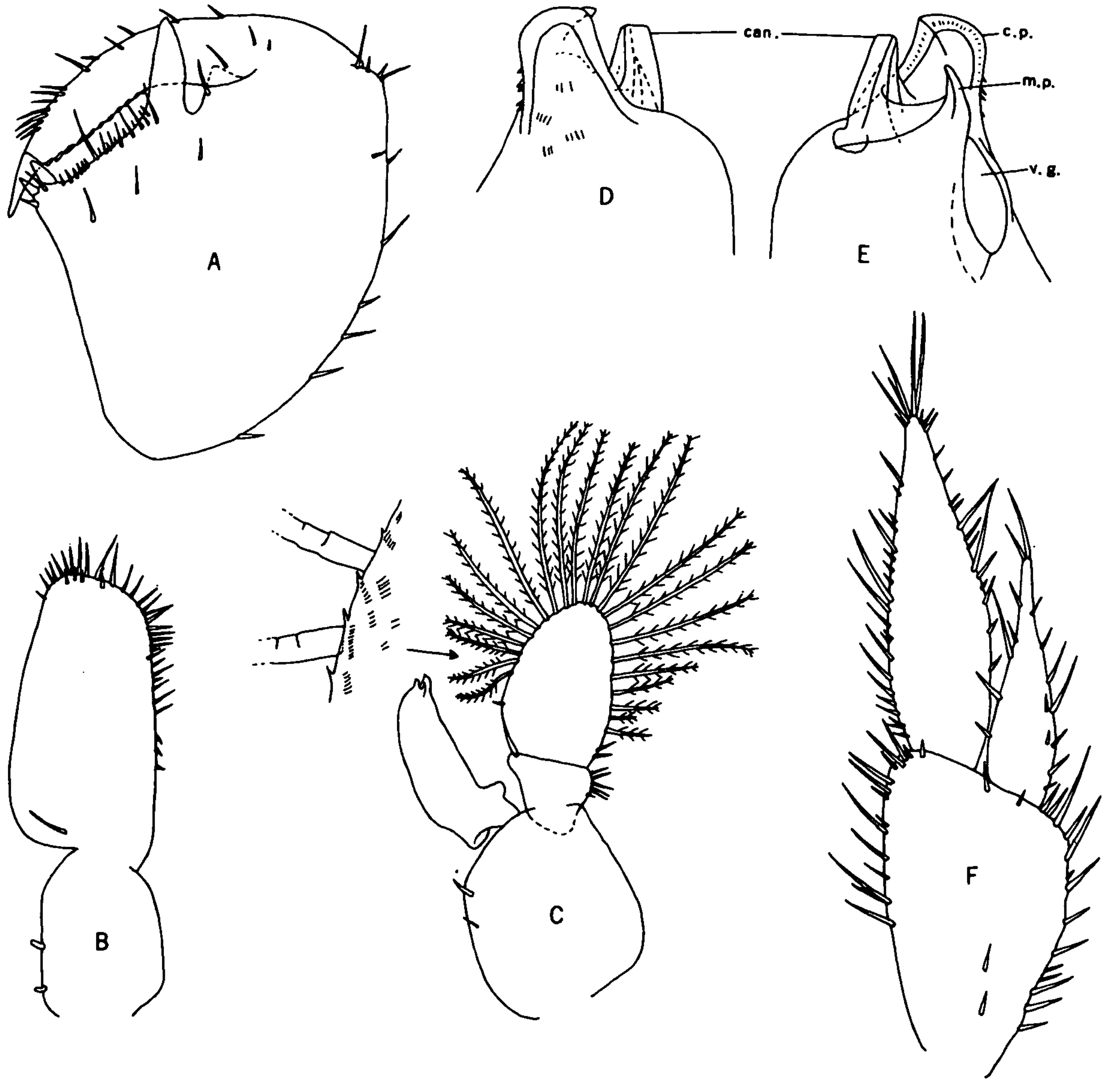


Fig. 18. *A. racovitzai racovitzai*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod. (After Williams, 1970).
can.= cannula, c.p.= caudal process, m.p.= mesial process, v.g.= ventral groove.

8(7) Distal segment of pleopod 1 more or less subrectangular (Fig. 18B). Cannula of pleopod 2 triangular in shape, not markedly thickened on outer margin (Figs 18D, E, 19A-J); shape of endopod and proportions of segments as in Fig. 18C. (Table 1): *A. racovitzai racovitzai*

Distal segment of pleopod 1 more or less subovate (Fig. 20A-H). Cannula of pleopod 2 not conspicuously triangular in shape, and outer margin thickened (Figs 21D, E, 22A-F); shape of endopod and proportions of segments as in Fig. 21C. (Table 1): *A. racovitzai australis*

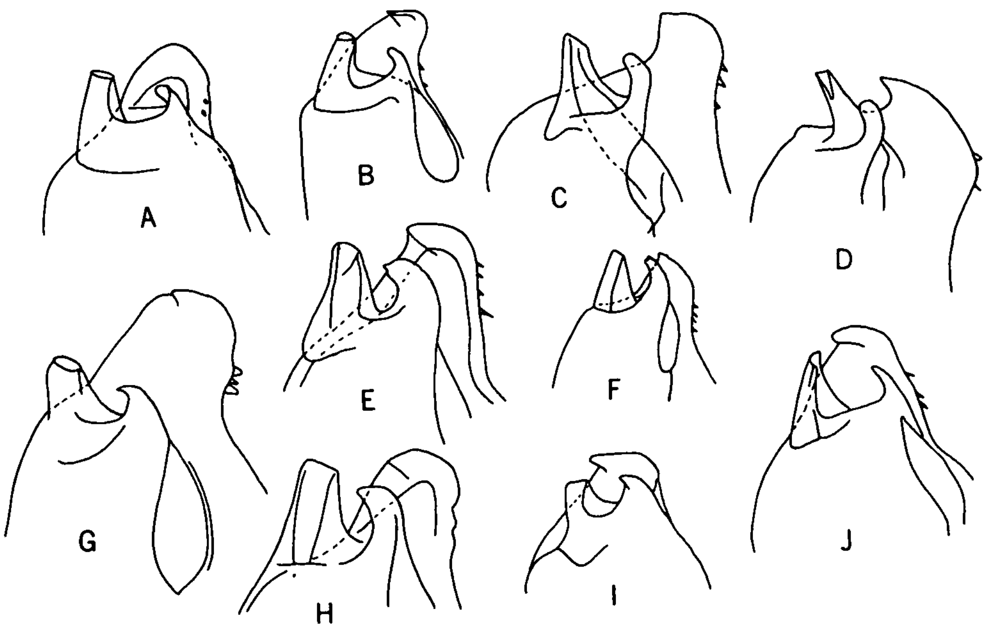


Fig. 19. *A. racovitzai racovitzai.* Variation in morphology of tip of endopod of second pleopod. A-J, ventral views; A-H, J, specimens from eastern States and southeastern Canada; I, specimen from Washington. From Williams (1970).

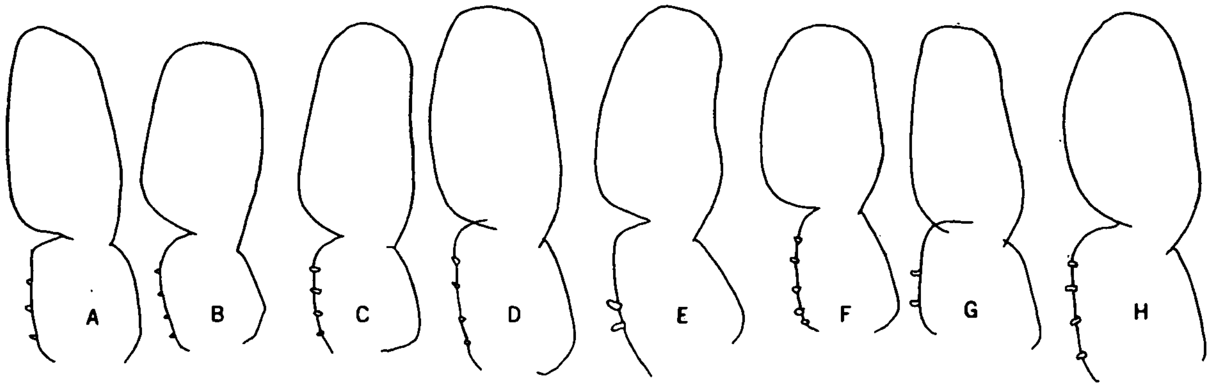


Fig. 20. *A. racovitzai racovitzai.* Variation in shape of first pleopod.

TABLE 1

SOME DIFFERENCES BETWEEN TWO SUBSPECIES OF *ASELLUS RACOVITZAI*
(males only)

(From Williams 1970, Table 4)

		A. racovitzai racovitzai	*A. racovitzai australis*
length of antenna 2 / body length	Range	0.44-0.80	0.67-1.00
	M*	0.60	0.80
	± S.D.	0.08	0.09
Pleopod 2: length of endopod / length of distal segment of exopod	Range	1.05-1.89	0.72-1.20
	M*	1.34	0.96
	± S.D.	0.18	0.11
Pleopod 2-distal segment of exopod: length / width	Range	0.96-2.00	1.48-2.47
	M*	1.45	1.78
	± S.D.	0.20	0.25
Pleopod 2-endopod: length / width	Range	2.34-3.20	2.15-2.80
	M*	2.78	2.49
	+ S.D.	0.24	0.17

* difference between means highly significant in all comparisons (by "t" test, P =< 0.001)

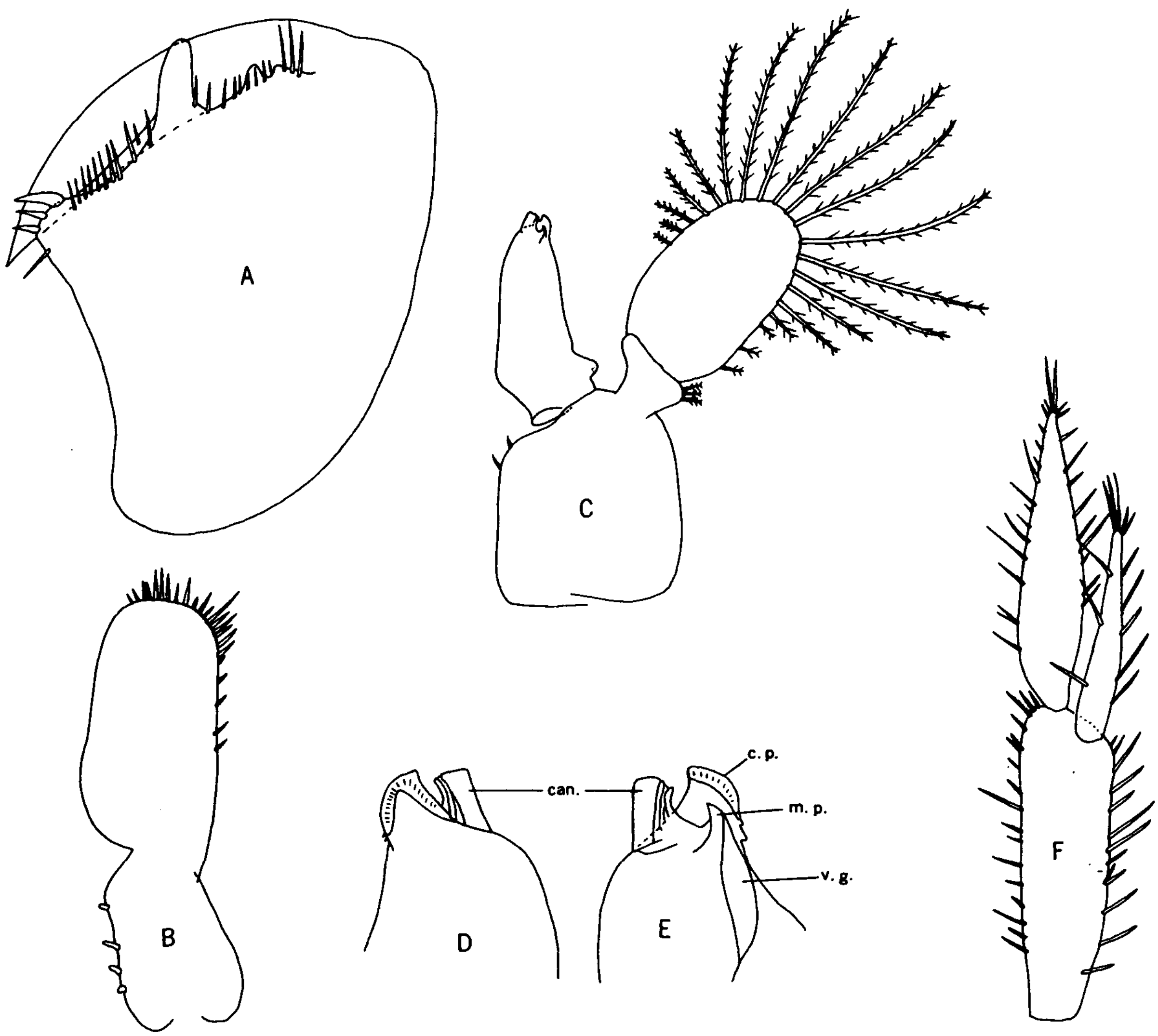


Fig. 21. *A. racovitzai australis.* A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod. (After Williams, 1970).
can.= cannula, c.p.= caudal process, m.p.= mesial process, v.g.= ventral groove.

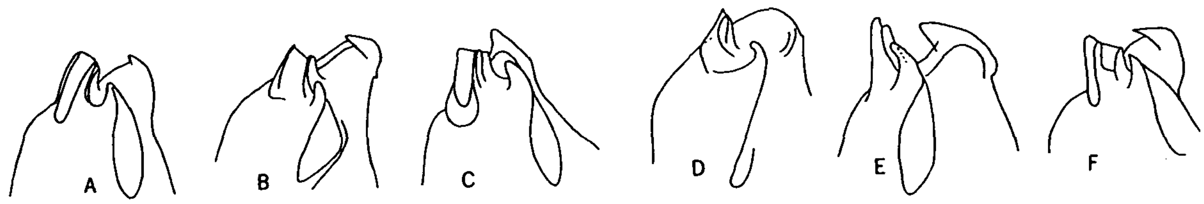


Fig. 22. *A. racovitzai australis.* Variation in morphology of tip of endopod of second pleopod. A-F, ventral views. From Williams (1970).

9(6) Antenna 2 usually shorter than body length. Proximal projection on palm of propodus of peraeopod 1 typically with tooth-like seta (Fig. 23A). Mesial process of pleopod 2 usually long and not very wide; cannula of moderate width (Figs 23D, E, 24A-G); endopod shape and/or proportions of segments as in Figs 23C, 25A-J; proximal segment of exopod frequently with marginal setae (Fig. 23C). Uropods mostly subequal in length to telson. Both telson and uropods only moderately setose laterally (Fig. 23F, G) (Table 2): *A. forbesi*

Antenna 2 usually subequal in length to body. Proximal projection on palm of propodus of peraeopod 1 with long stout seta (never a tooth-like seta) (Fig. 26). Mesial process of pleopod 2 usually short and wide, cannula very wide with recurved outer lip (Figs 27C, D, 28A-H); endopod shape and proportions of segments as in Fig. 27B; proximal segment of exopod without marginal setae (Fig. 27B). Uropods distinctly longer than telson and both telson and uropods very setose laterally (Fig. 27E) (Table 2): *A. obtusus*

10(2) Body of endopod and associated terminal processes of pleopod 2 arranged in spiral fashion so that 'ventral' groove actually lies dorsally (Fig. 29C, D, E); cannula not visible; endopod shape and proportions of segments as in Fig. 29C. Endopod of uropod shorter than peduncle (Fig. 29F): *A. montanus*

Body of endopod of pleopod 2 not spirally arranged although some torsion may be displayed by terminal processes (i.e. not as indicated in Fig. 29C, D, E); cannula (at least tip) visible from ventral or dorsal view; endopod shape and proportions of segments more or less dissimilar to Fig. 29C. Endopod of uropod typically longer than or subequal in length to peduncle 11

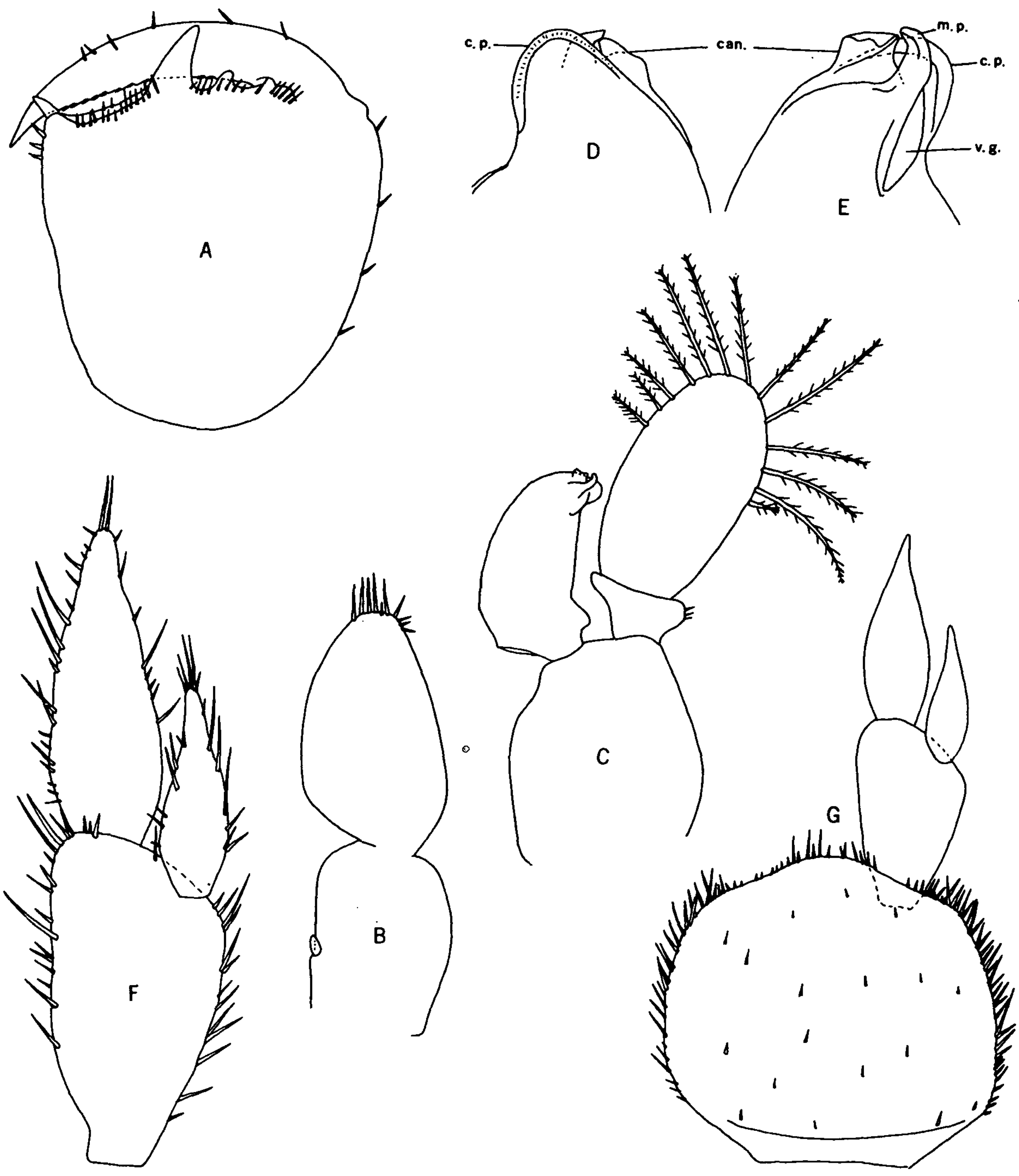


Fig. 23. *A. forbesi*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surface of tip of endopod of second pleopod; F, uropod; G, uropod and telson. (After Williams, 1970).
can.= cannula, c.p.= caudal process, m.p.= mesial process, v.g.= ventral groove.

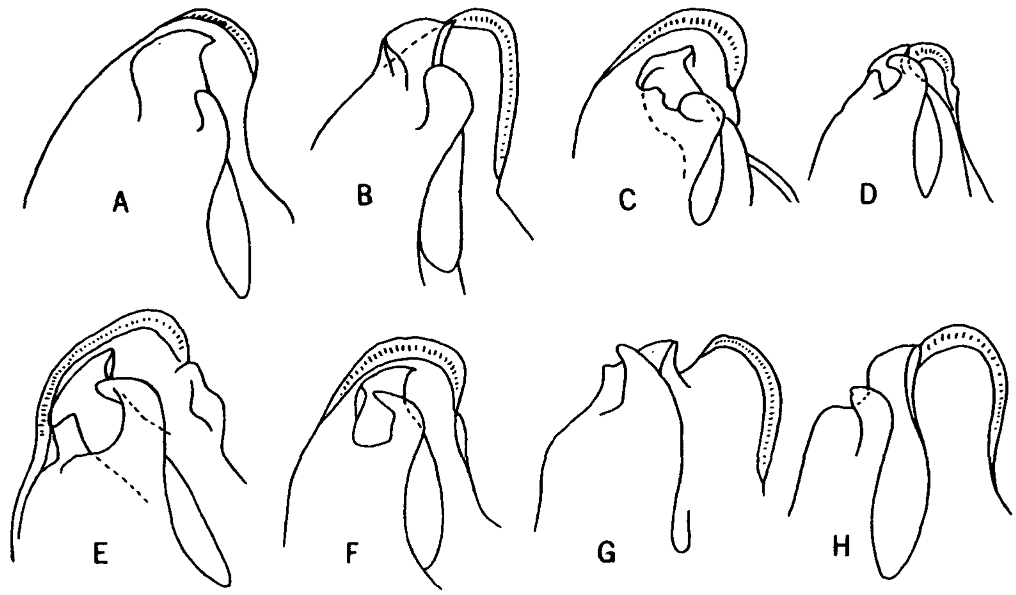


Fig. 24. *A. forbesi.* Variation in morphology of tip of endopod of second pleopod. A-H, ventral views. From Williams (1970).

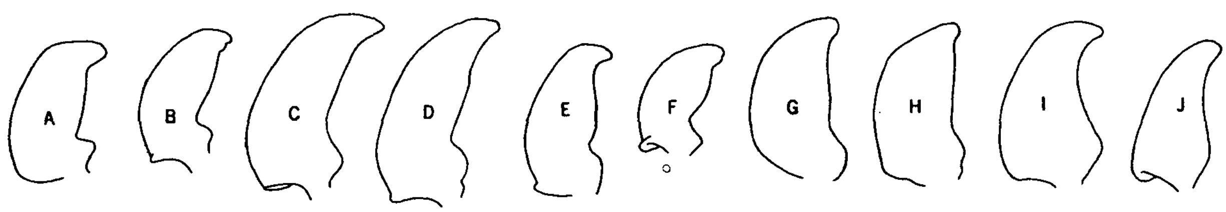
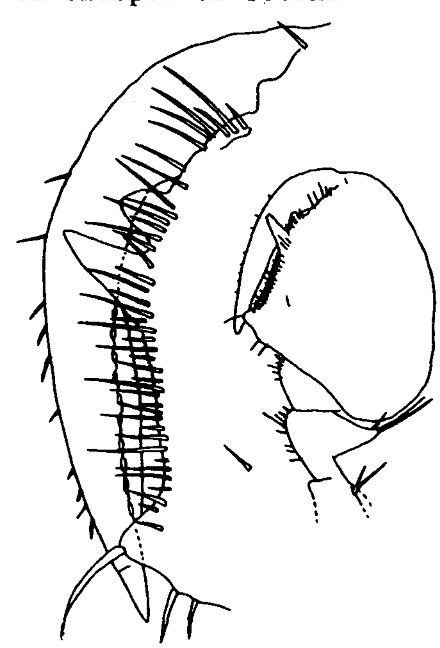


Fig. 25. *A. forbesi.* Variation in shape of endopod of second pleopod. From Williams (1970).

Fig. 26. *A. obtusus.* Distal segments of first peraeopod with dactylus and palm of propodus shown in greater detail. From Williams (1970).



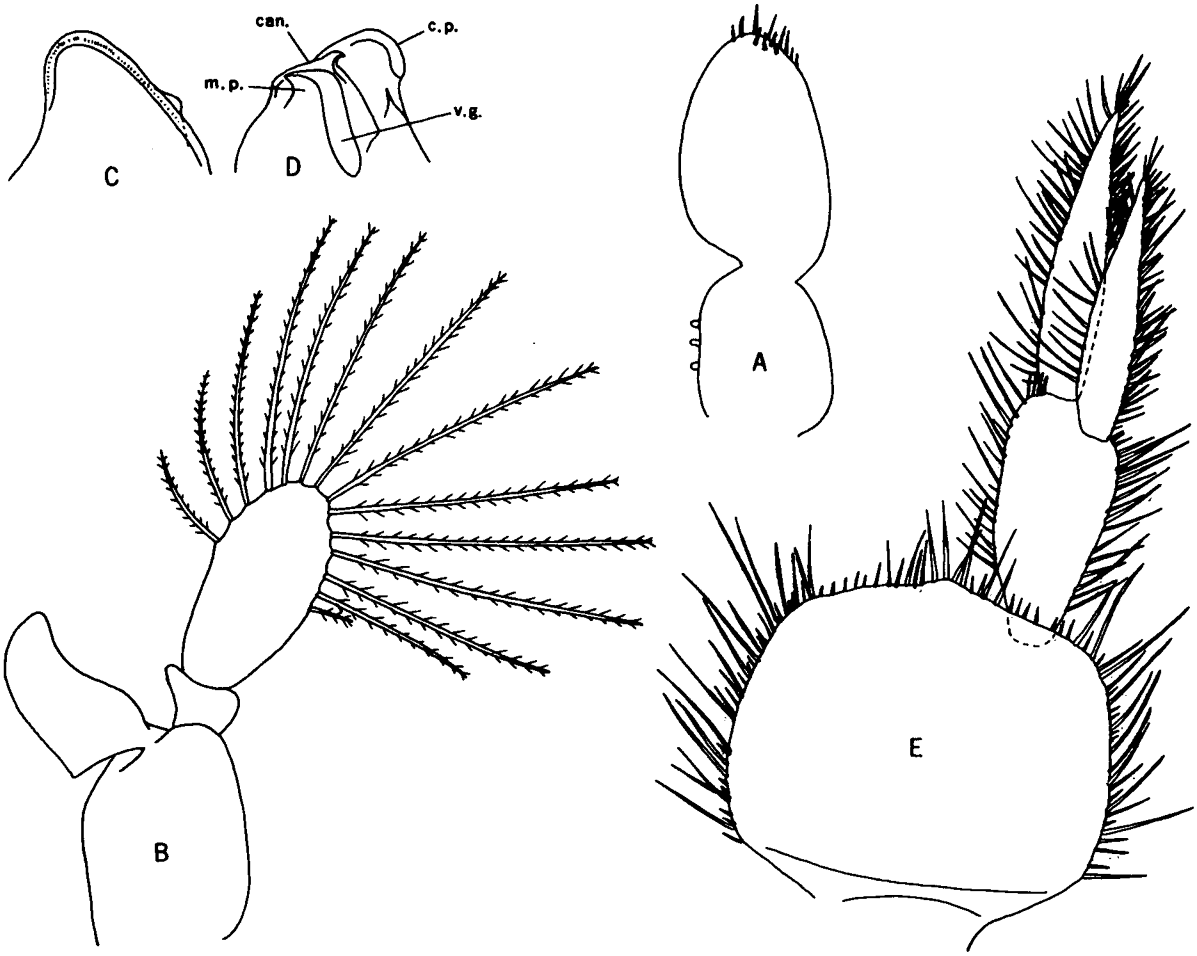


Fig. 27. *A. obtusus*. A, first pleopod; B, second pleopod; C, D, respectively dorsal and ventral surfaces of endopod of second pleopod; E, uropod and telson. (After Williams, 1970).
can.= cannula, c.p.= caudal process, m.p.= mesial process, v.g.= ventral groove.

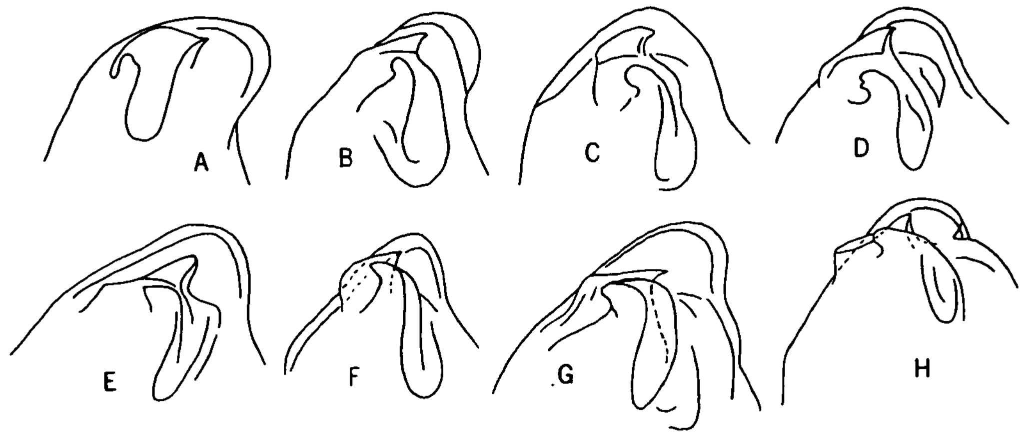


Fig. 28. *A. obtusus*. Variation in morphology of tip of endopod of second pleopod. A-H, ventral views. From Williams (1970).

TABLE 2

SOME DIFFERENCES BETWEEN TWO SPECIES OF *ASELLUS* (males only)
(From Williams 1970, Table 5)

		A. forbesi	*A. obtusus*
Maximum body length (mm)		18.5	12.5
length of antenna 2 / body length	Range	0.5-1.0	0.8-1.5
	M*	0.75	1.03
	± S.D.	0.12	0.19
Pleopod 2-proximal segment of exopod Number of marginal setae		0-4	0
Pleopod 2-endopod length / width	Range	1.65-2.64	1.39-1.84
	M*	2.05	1.63
	± S.D.	0.22	0.15
uropod length / telson length	Range	0.67-1.5	1.0-2.0
	M*	1.16	1.48
	± S.D.	0.20	0.32

* difference between means highly significant in all comparisons (by "t" test, P = < 0.001)

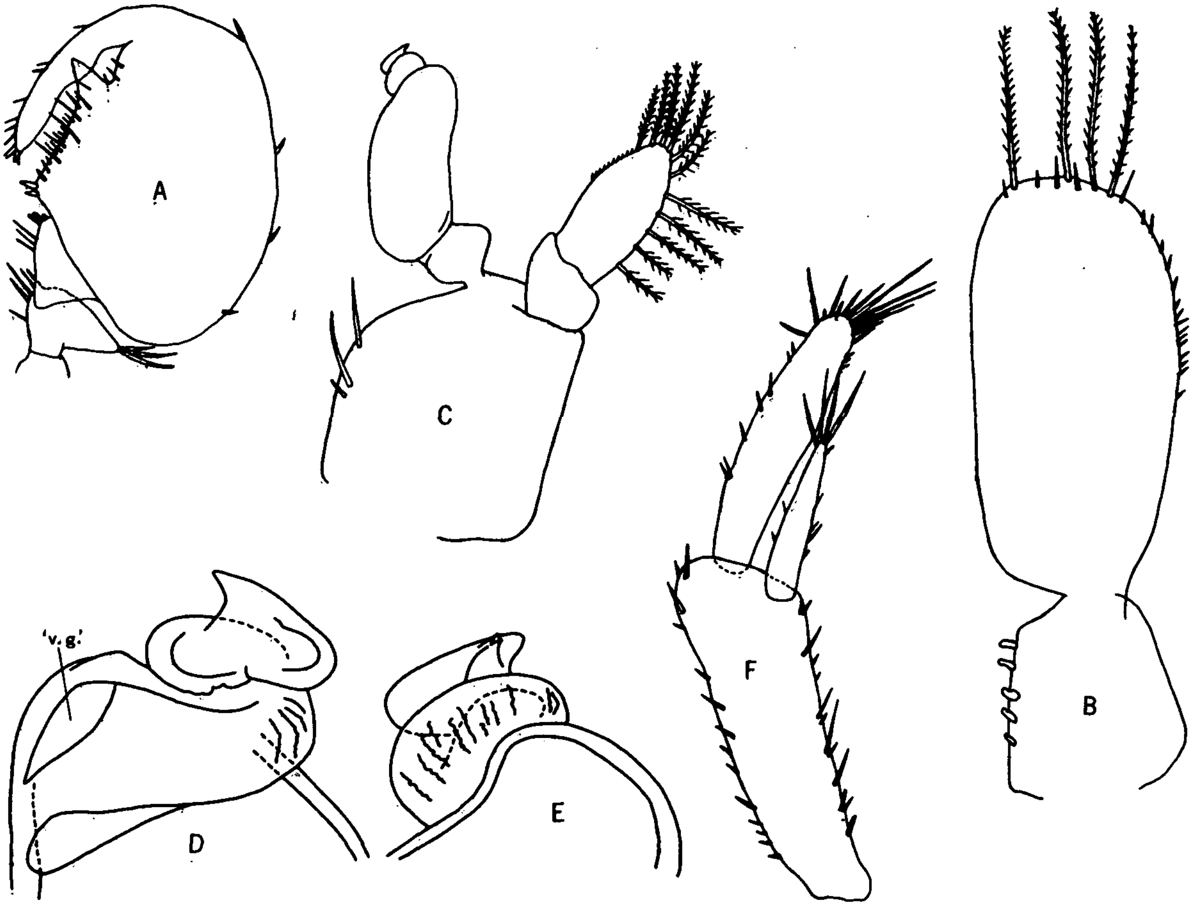


Fig. 29. *A. montanus:* A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod. (After Williams, 1970).
'v.g.'= 'ventral' groove.

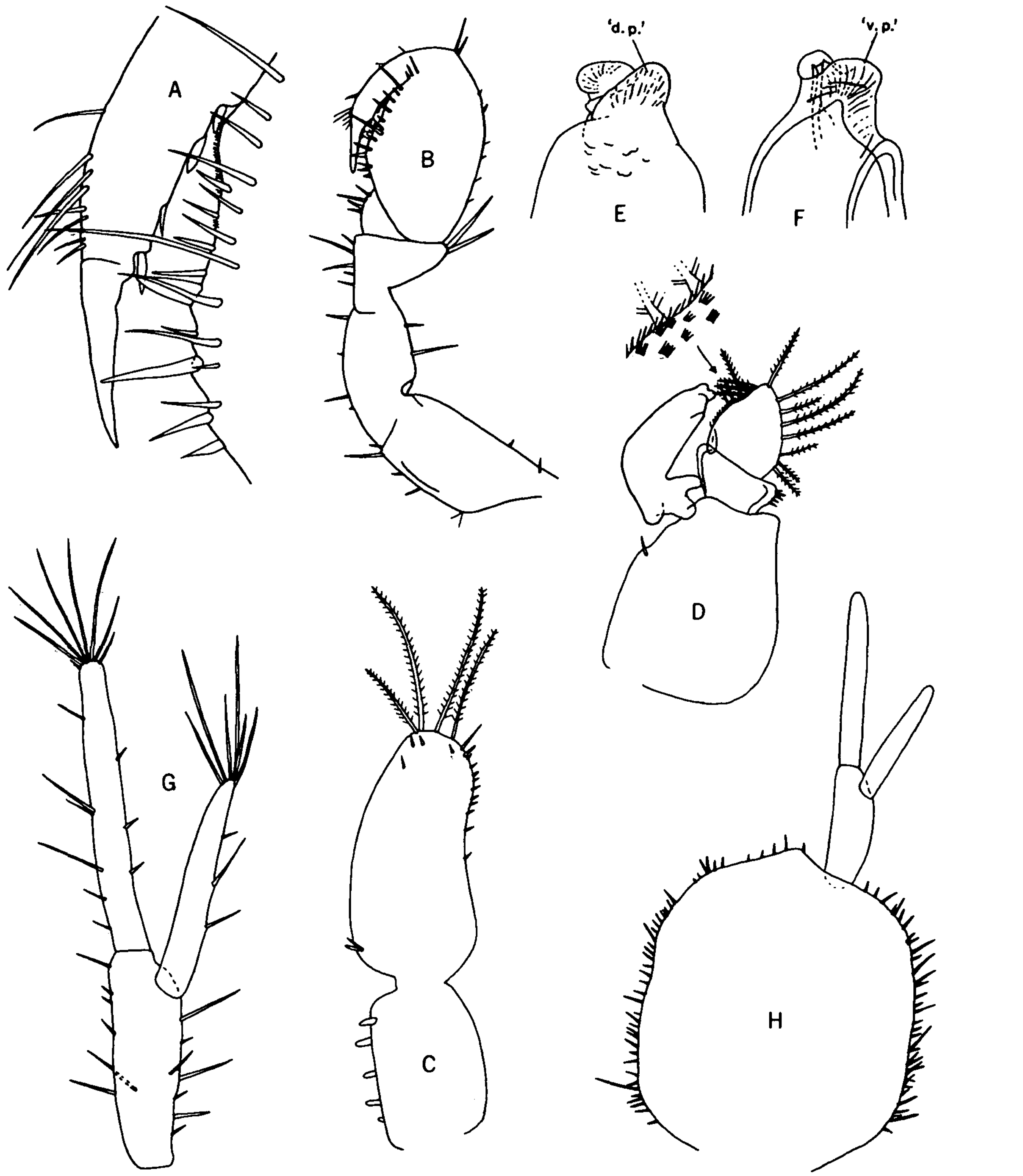


Fig. 30. *A. nodulus*. A, dactylus and palm of first peraeopod; B, first peraeopod; C, first pleopod; D, second pleopod; E, F, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; G, uropod; H, uropod and telson. (After Williams, 1970). 'd.p.'= dorsal process, 'v.p.'= ventral process.

11(10) Cannula of pleopod 2 completely enclosed between two prominent, heavily sclerotized, non-dentate, broadly rounded 'ventral' and 'dorsal' processes (Fig. 30E, F); distal end of endopod with small degree of torsion so that 'ventral' groove lies laterally; endopod shape and proportions of segments as in Fig. 30D. Endopod of uropod distinctly longer than peduncle (Fig. 30G, H): *A. nodulus*

Cannula of pleopod 2 not enclosed between two processes as described above (i.e. not as indicated in Fig. 30E, F); distal end of endopod not displaying any obvious sign of torsion; ventral groove distinct; endopod shape and proportions of segments more or less dissimilar to drawing of Fig. 30D. Endopod of uropod typically only slightly longer than or subequal in length to peduncle 12

12(11) Cannula of pleopod 2 visible from ventral view, lateral process not (or only slightly) developed, mesial process prominent and bifid, caudal process wide and irregularly dentate (Fig. 31D, E); endopod shape and proportions of segments as in Fig. 31C: *A. dentadactylus*

Cannula of pleopod 2 often hidden by lateral process in ventral view, lateral process well-developed, mesial process prominent but with either rounded or dentate distal margin (not bifid), caudal process absent or rounded (not dentate); endopod shape and proportions of segments more or less dissimilar to Fig. 31C 13

13(12) Caudal process of pleopod 2 absent, distal dorsal surface of endopod with numerous minute setae, lateral process non-sclerotized with rounded margin, mesial process obtusely dentate (Fig. 32C, D); endopod shape and proportions of segments with some variation but typically as shown in Figs 32B, 33A-G. Uropods about half as long as telson (always <0.7), peduncle about as wide as long (Fig. 32E): *A. brevicauda brevicauda*

[Pending a further examination of specimens, two subspecies of *A. brevicauda* have tentatively been proposed by Williams (1970), *A. brevicauda brevicauda* Forbes, 1876, and *A. brevicauda bivittatus* Walker, 1961. The differences between them are small and mainly involve slight differences in setation, segment proportions, and number of segments in antennal flagella. Table 3 details the principal differences.]

Distal endopodial processes of pleopod 2 (considered as a whole) of shape and arrangement other than as described for *A. brevicauda brevicauda*, distal dorsal surface of endopod lacks minute setae; endopod shape and proportions of segments more or less dissimilar to drawings of Figs 32B, 33A-G. Uropods subequal to or slightly longer than telson, peduncle always longer than wide. 14

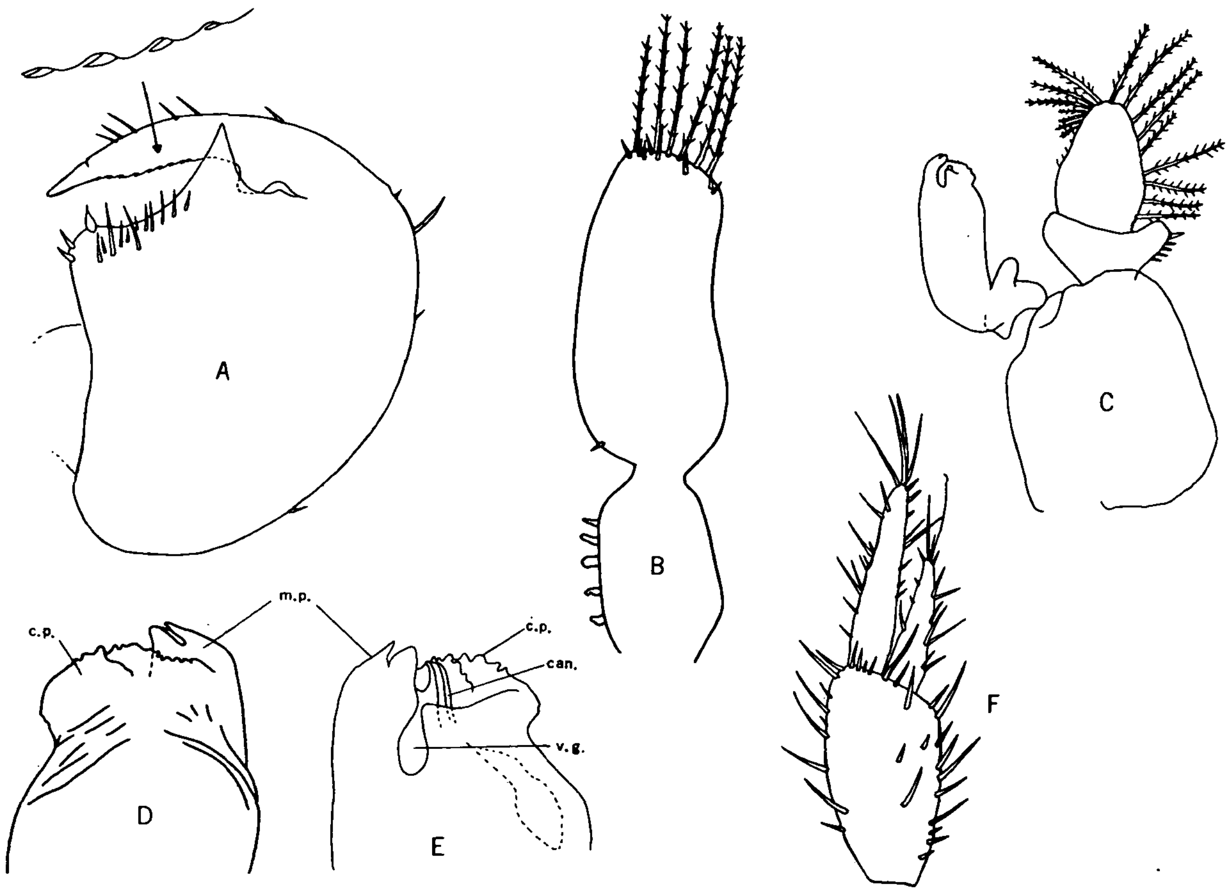


Fig. 31. *A. dentadactylus*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod. (After Williams, 1970).
can.= cannula, c.p.= caudal process, m.p.= mesial process, v.g.= ventral groove.

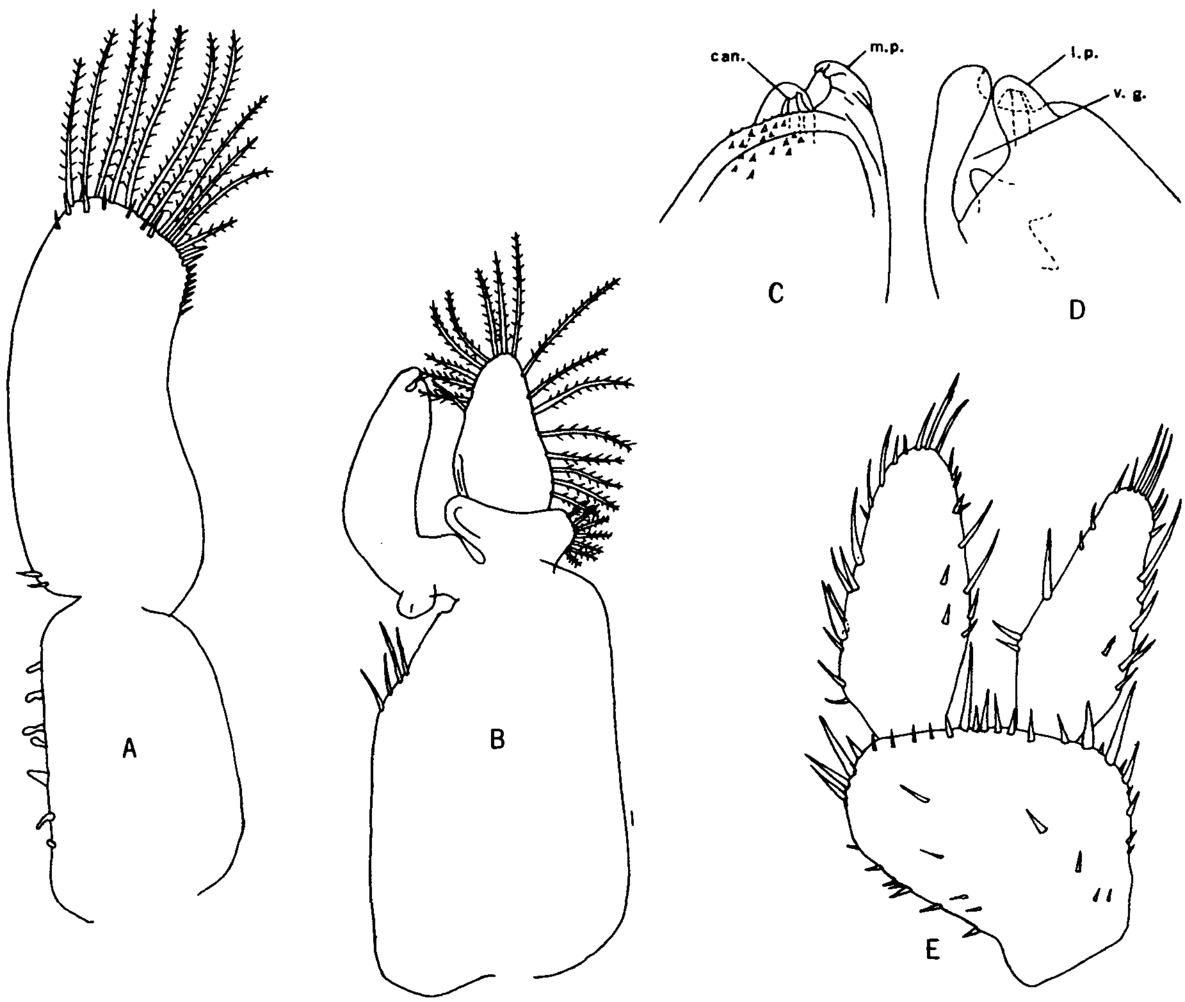


Fig. 32. *A. brevicauda brevicauda.* A, first pleopod; B, second pleopod; C, D, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; E, uropod. (After Williams, 1970). can.= cannula, l.p.= lateral process, m.p.= mesial process, v.g.= ventral groove.

14(13) Cannula of pleopod 2 small and narrow, lateral process pointed, mesial process obtusely dentate, caudal process absent (Figs 34D, E, 35A-G); endopod shape and proportions of segments as in Fig. 34C: *A. scrupulosus*

Cannula of pleopod 2 not small and narrow, lateral process rounded, mesial process not dentate (but with rugose posterior lobe), caudal process present, broadly rounded with some rugosities (Fig. 36D, E); endopod shape and proportions of segments as in Fig. 36C: *A. kenki*

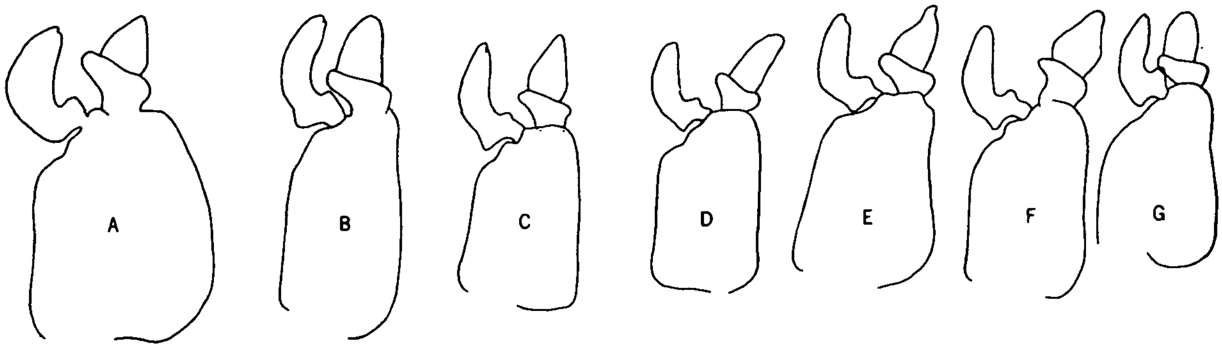


Fig. 33. *A. brevicauda brevicauda.* Variation in shape and proportions of segments of second pleopod. From Williams (1970).

TABLE 3

PRINCIPAL DIFFERENCES BETWEEN TWO SUBSPECIES OF *ASELLUS BREVICAUDA* (males only)

(From Williams 1970, Table 3)

		A. brevicauda brevicauda	*A. brevicauda bivittatus*
	Maximum body length (mm)	17.0	5.5
Antenna 1	No. segments in flagellum	11-17	8-9
Antenna 2	No. segments in flagellum	60-124	31-44
Peraeopod 1	No. teeth-like setae on dactylus	6-14	5-6
	Triangular process near mid-point of palm of propodus	present	absent
Pleopod 1	No. coupling hooks on sympod	4-7	3-4
	$\frac{\text{width}}{\text{length}}$ distal segment	0.40-0.50	0.50-0.62
	No. plumose setae on distal segment	5-11	4-6
Pleopod 2	$\frac{\text{length}}{\text{width}}$ sympod	1.37-2.00	1.25-1.60
	No. plumose setae on distal segment of exopod	12-17	5-10
	$\frac{\text{uropod length}}{\text{telson length}}$	0.48-0.68	0.36-0.44

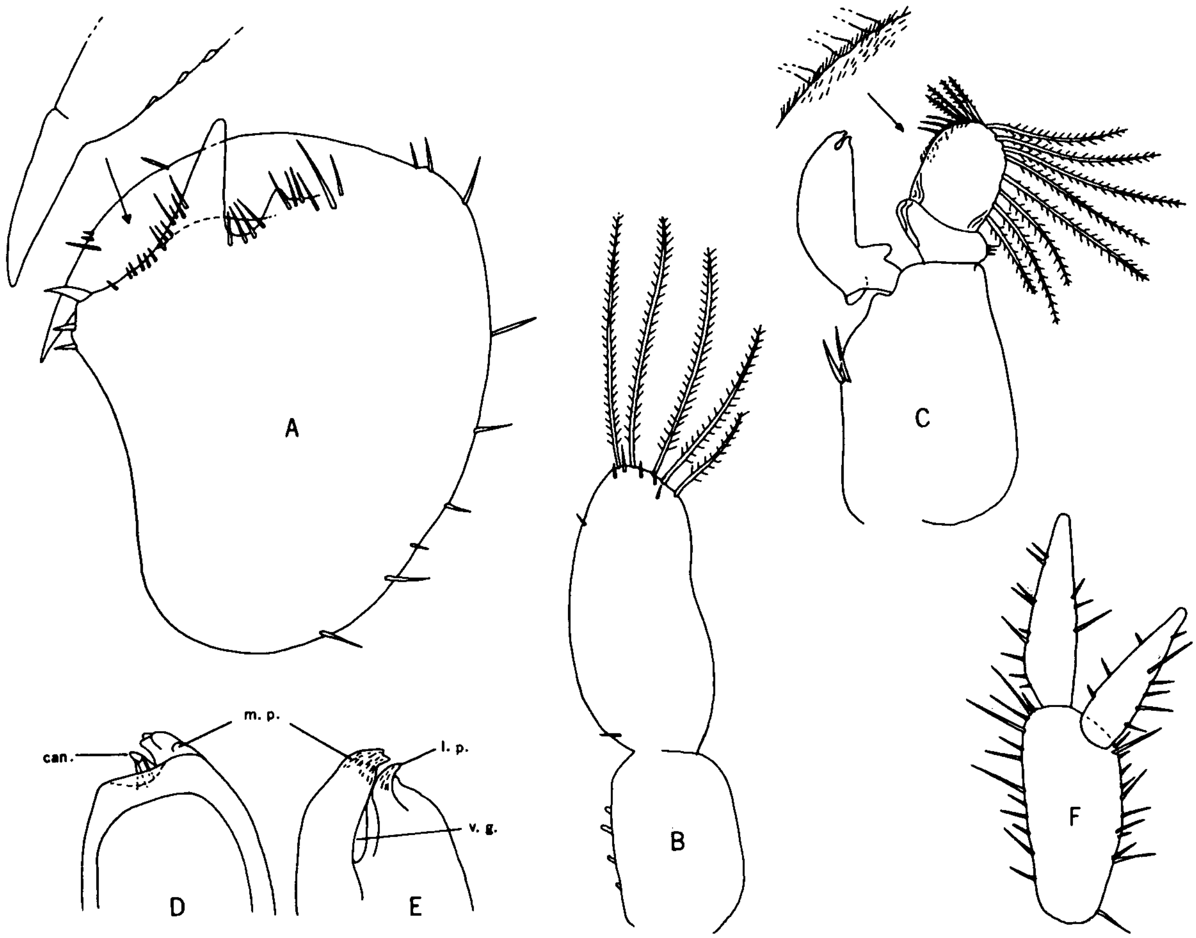


Fig. 34. *A. scrupulosus*. A, dactylus and propodus of first peraeopod; B, first pleopod; C, second pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second pleopod; F, uropod. (After Williams, 1970).
can.= cannula, l.p.= lateral process, m.p.= mesial process, v.g.= ventral groove.

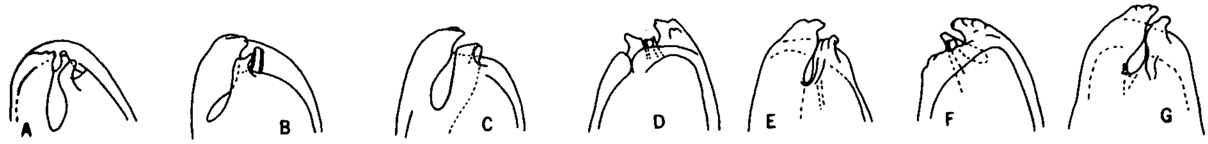


Fig. 35. *A. scrupulosus*. Variation in morphology of endopod tip of second pleopod. A-C, E, G, ventral views; D, F, dorsal views. From Williams (1970).

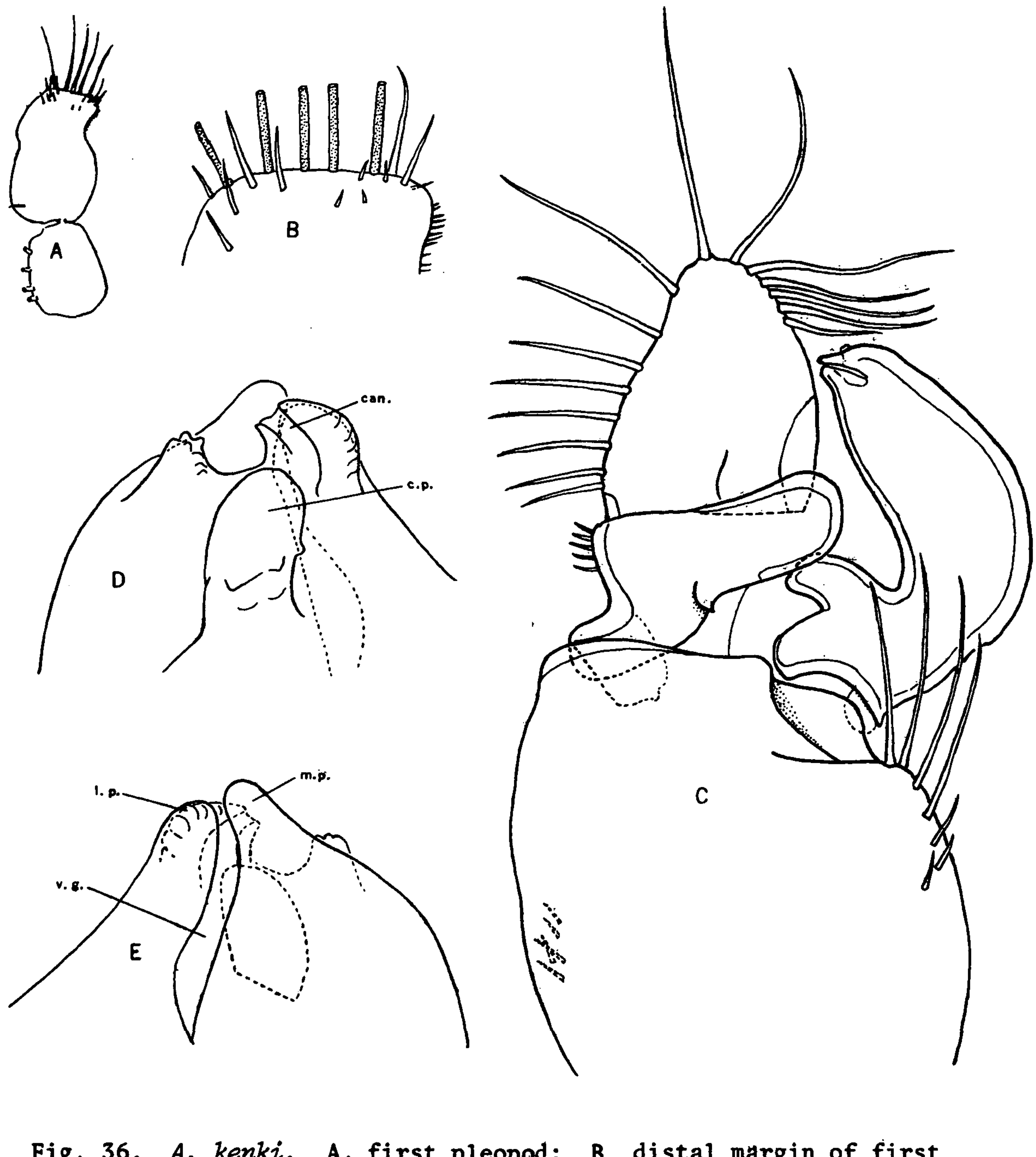


Fig. 36. *A. kenki*. A, first pleopod; B, distal margin of first pleopod; C, second left pleopod; D, E, respectively dorsal and ventral surfaces of tip of endopod of second left pleopod. (After Bowman, 1967) can.= cannula, c.p.= caudal process, l.p.= lateral process, m.p.= mesial process, v.g.= ventral groove.

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