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A new family of cyclopoid copepods (Fratiidae) symbiotic in the ascidian (*Clavelina dellavallei*) from Cádiz, Spain

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Abstract

Fratia gaditana, n. gen., n. sp., is described based on the specimens obtained from the atrium of the ascidian, *Clavelina dellavallei* (Zirpolo), collected at Tarifa Island in Cádiz, Spain. The new species belongs to a new family of Cyclopoida. Cladistic analysis revealed that phylogenetically it is closer to the Ascidicolidae than to the two other ascidicolous families, Archinotodelphyidae and Notodelphyidae.

Key words: Copepoda, Cyclopoida, Fratiidae new family, ascidian, *Clavellina*

INTRODUCTION

Many sessile marine invertebrates, like sponges, bivalves, and ascidians, that constantly produce feeding-respiratory currents, harbour symbiotic copepods. While the structures that generate such currents in sponges are occupied mostly by siphonostomatoid copepods and in bivalves, by poecilostomatoid copepods, in ascidians they are colonized almost exclusively by cyclopoid copepods (Ho, 1994: 1297).

Three families of cyclopoids are parasitic in ascidians: Archinotodelphyidae, Ascidicolidae, and Notodelphyidae. In this paper we report a new family of cyclopoid copepods recovered from the atrium (branchial sac) of the ascidian, *Clavelina dellavallei* (Zirpolo, 1925), collected at Tarifa Island in Cádiz, Spain.

MATERIAL AND METHODS

On 15 October 1995, a colony of ascidians, *Clavelina dellavallei*, attached to a stone in the subtidal zone (15–20 m) at Tarifa Island in Cádiz, Spain was collected for examination. Two ovigerous females and one male copepod were recovered from the atrium of the ascidian zooids. Subsequent collections of the same host from the same locality yielded one adult female on 2 November 1995 and 16 specimens (5 ovigerous females, 5 adult males, and 6 juvenile females and copepodids) on 8 August 1996. The holotype female and allotype male have been deposited in the Museo Nacional de Ciencias Naturales of Madrid, Spain (MNCN lot no. 20.04/3887).

The copepods were preserved in 70% ethanol, stained with chlorazol black, then dissected for microscopic examination. The dissected appendages were mounted in lactophenol and sealed with entellan.

All drawings were made with the aid of a camera lucida. The letter after explanation of each figure refers to the scale at which it was drawn. A complete description is given of the female, and for the male only those features exhibiting sexual dimorphism are mentioned.

FRATIA N. GEN.

Diagnosis

Female

Body cyclopiform, with first pediger separated from cephalosome. Urosome 5-segmented. Antennule 8-segmented, with large aesthete on segments 4 and 6–8. Antenna 4-segmented, without claw. Mandibular palp reduced to a single ramus and indistinctly 2-segmented, first segment with 1 seta and second segment with 4 setae. Maxillule bilobate, with 7 setae on inner lobe and 4 setae on outer lobe. Maxilla 3-segmented; third segment representing reduced endopod and carrying 3 setae. Maxilliped 4-segmented; terminal segment a large claw. Legs 1–4 biramous with 3-segmented rami, except endopod of leg 4 which is 2-segmented. Leg 5 2-segmented, armature 1-0; I, I, II.

Male

More slender than female. Urosome 6-segmented. Antennule 8-segmented, not geniculate, with three addi-

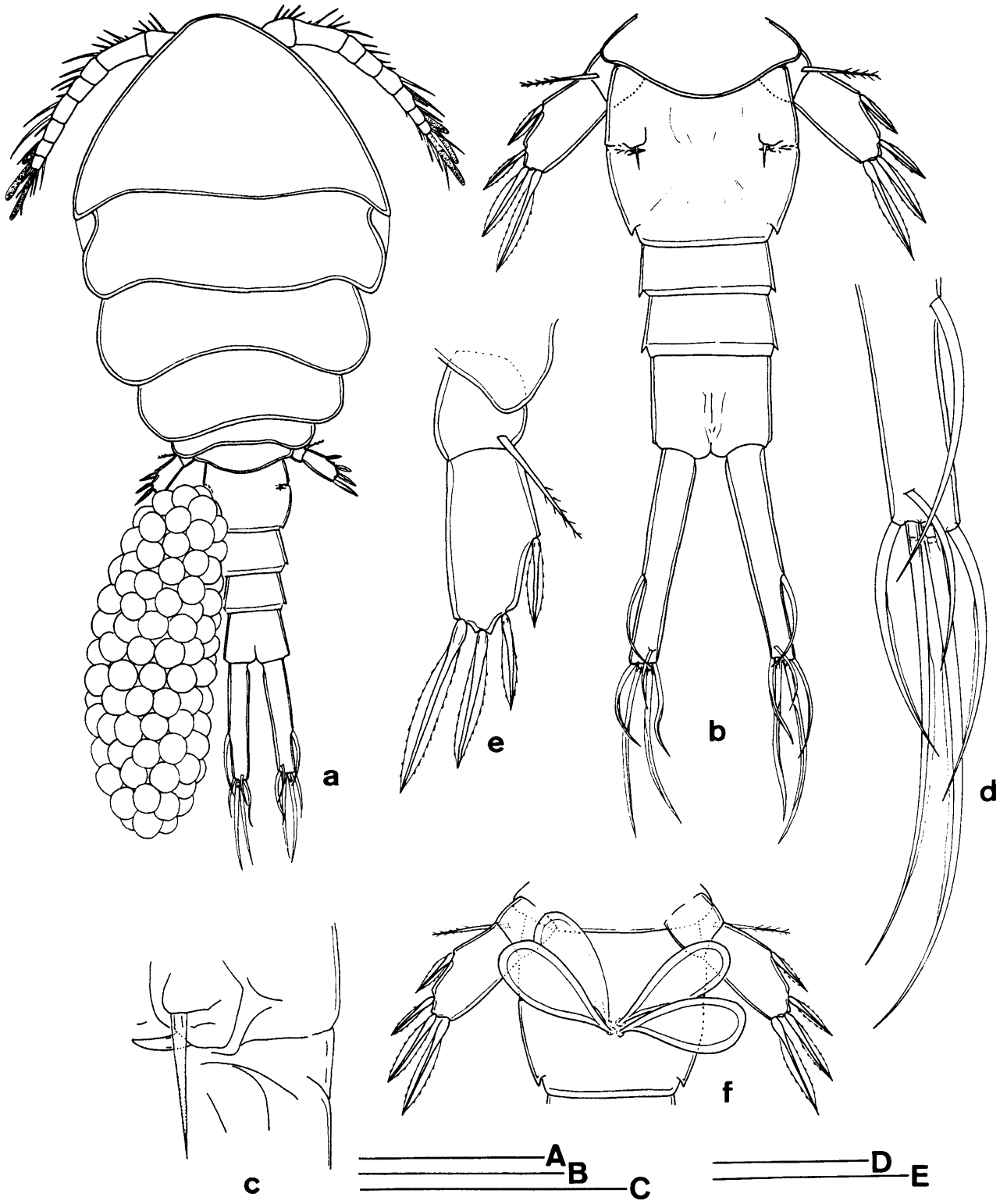

Fig. 1. *Fratia gaditana*, n. gen., n. sp. Female: a, dorsal (A); b, urosome, dorsal (B); c, genital aperture, dorsal (C); d, distal part of caudal ramus, dorsal (D); e, leg 5, dorsal (E); f, genital double-somite with attached spermatophores, ventral (B). Scale bars: A, 300 μm; B, 200 μm; C, 50 μm; D, 150 μm; E, 110 μm.

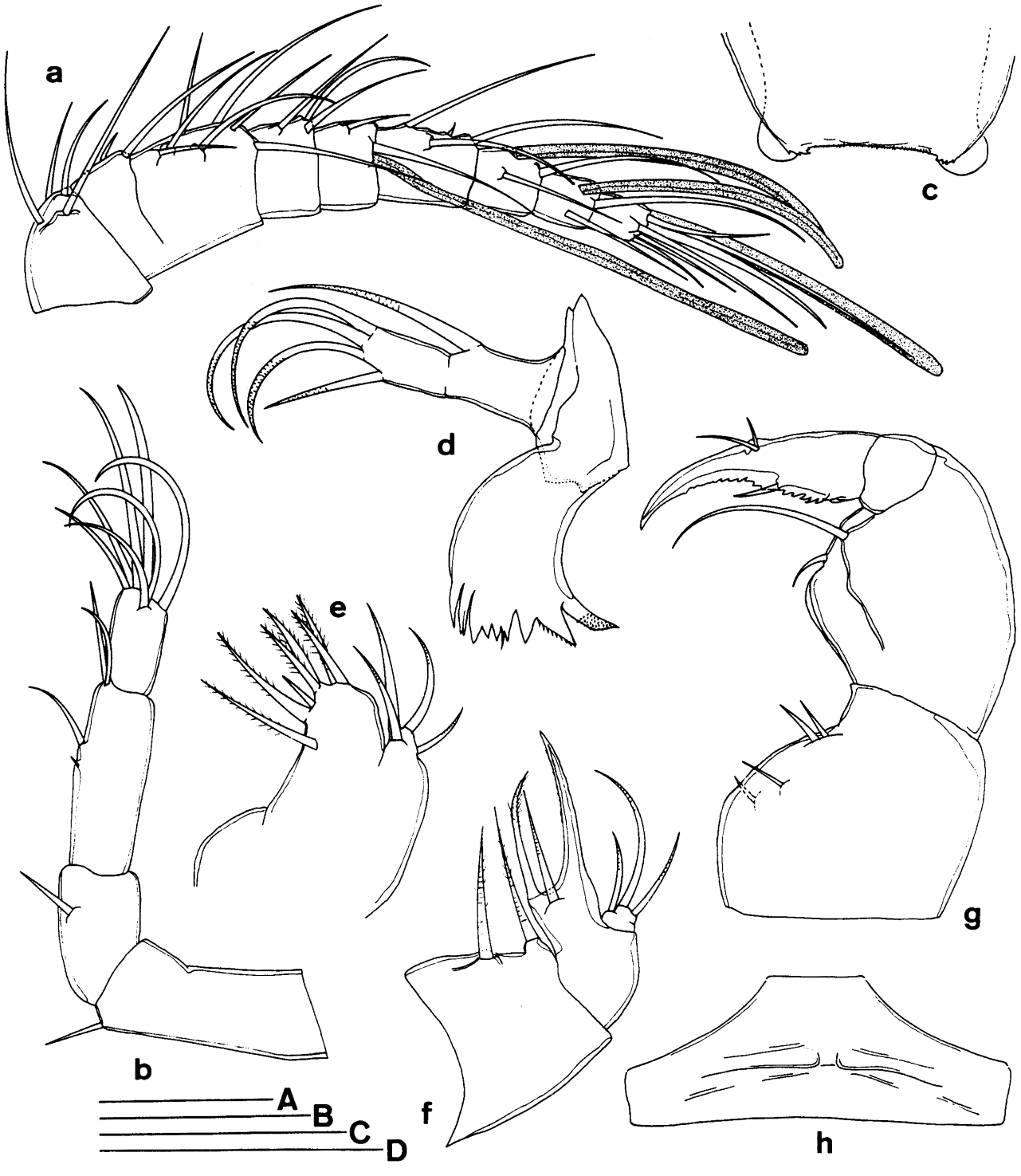

Fig. 2. *Fratia gaditana*, n. gen., n. sp. Female: a, antennule, ventral (A); b, antenna (B); c, labrum, ventral (B); d, mandible (C); e, maxillule (C); f, maxilla (C); g, maxilliped (C); h, area between maxilliped and first pair of legs, ventral (D). Scale bars: A, 100 μm; B, 100 μm; C, 80 μm; D, 150 μm.

tional aesthetes: 2 on 2nd and 1 on 3rd segments. Maxillule with 6 setae on inner lobe. Maxilliped with a longer terminal claw. Legs 1–4 biramous with 3-segmented exopods and 2-segmented endopods, except endopod of leg 1 which is 3-segmented.

Type species

Fratia gaditana n. sp.

Etymology

The generic name is an anagram of Tarifa where the new form was discovered.

Gender

Feminine.

FRATIA GADITANA N. SP.

(Figs 1–5)

Description

Female (Figs 1–3)

Body cyclopiform (Fig. 1a), 1.2 mm long (excluding setae on caudal rami) and 505.8 μm wide. First pediger separate from cephalosome. Urosome 5-segmented, genital double-somite (Fig. 1b) slightly wider than long (170 × 185 μm). Genital apertures (Fig. 1c) located dorsoventrally on widest part of somite and bearing one seta (26.3 μm) and one spine (10 μm). Abdominal somites wider than long, but anal somite about as wide as long. Caudal ramus (Fig. 1b) about 5 times longer than wide and bearing 6 setae. Four terminal setae (III, IV, V, VI) with a thin membrane on medial edge (Fig. 1d). Egg sac (Fig. 1a) oval, 240 × 112 μm; densely packed with many eggs, each about 50 μm in diameter.

Rostrum rounded posteroventrally. Antennule (Fig. 2a) 8-segmented, with second segment subdivided by incomplete suture. Segmental armature: 4, 9, 3, 2+1 aesthete, 4, 2+1 aesthete, 2+1 aesthete and 6+1 aesthete. All setae naked. Antenna (Fig. 2b) 4-segmented; formula of armature 1, 1, 4, 7; two inner-most terminal setae curved, but not spiniform. Labrum (Fig. 2c) with serrated edge on posterolateral corners overlying paired, small fleshy, lobes. Terminal edge of mandibular gnathobase well-armed as in Fig. 2d; mandibular palp simple, indistinctly 2-segmented, basal segment with 1 outer seta (remnant of exopod) and terminal segment tipped with 3 terminal setae and 1 subterminal inner seta. Maxillule (Fig. 2e) bilobate; inner lobe carrying 6 ornamented setae and 1 simple, short seta, and outer lobe with 4 simple setae. Maxilla (Fig. 2f) 3-segmented; basal segment (syncoxa) bearing 2 ornamented setae on papilla, middle segment (basis) produced into a claw-like process and carrying 2 setae. Terminal segment representing reduced endopod, indistinctly bipartite and bearing 3 setae. Maxilliped (Fig. 2g) 4-segmented; first segment (syncoxa) largest and with 4 short setae, and second segment (basis) with 2 unequal setae. Distal two segments representing endopod, unarmed on basal segment but equipped with 3 short setae and serrated inner edge on claw-like terminal segment. Ventral area between maxillipeds and leg 1 (Fig. 2h) slightly protuberant.

Legs 1–4 (Figs. 3a–d) biramous and with 3-segmented rami, except leg 4 endopod which is 2-segmented. Formula for armature as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-I	I-0; I-1; III,I,4	0-1; 0-1; II,4
Leg 2	0-1	1-0	I-0; I-1; III,I,5	0-1; 0-2; I,III,2
Leg 3	0-1	1-0	I-0; I-1; III,I,5	0-1; 0-2; I,III,2
Leg 4	0-1	1-0	I-0; I-1; II,I,5	0-1; I,II,I,1

Leg 5 (Fig. 1e) 2-segmented; armature being: 0-1; IV. Leg 6 represented by small operculum with 1 spiniform seta and 1 spinous process, closing off genital aperature (Fig. 1c).

Male (Figs 4–5)

Body (Fig. 4a) more slender than female, 780 μm long and 210 μm wide. Genital somite (Fig. 4b) with ventral ridge protruded posterolaterally, with a dorsal barbed seta, and tipped with 1 naked seta and 1 short spine. Caudal ramus (Fig. 4b) slender, 109.5 x 14.2 μm. Antennule (Fig. 4c) indistinctly 8-segmented, with partial fusion between segments 2 and 3; armature: 4, 11+2 aesthetes, 3+1 aesthete, 1, 1+1 aesthete, 3+1 aesthete, 4+1 aesthete, and 6+2 aesthetes. Smaller seta on third segment of antenna in female missing in male. Labrum (Fig. 4d) different from female on posterior margin and lateral lobe. Inner lobe of maxillule (Fig. 4e) with 6 ornamented setae. Basis (2nd segment) of maxilliped (Fig. 4f) with swollen median surface carrying a dense patch of denticles; terminal claw stronger.

Legs 1–4 (Figs. 5a–d) biramous; segmentation and armature as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-I	I-0; I-1; III,I,4	0-1; 0-1; II,4
Leg 2	0-1	1-0	I-0; I-1; III,I,5	0-1; II,II,4
Leg 3	0-1	1-0	I-0; I-1; II,I,5	0-1; I,III,4
Leg 4	0-1	1-0	I-0; I-1; I,II,5	0-1; I,II,I,1

Spermatophore (Fig. 1f) measuring 110 × 50 μm (excluding neck), teardrop-shaped and attached in pairs to female copulatory pores.

Etymology

The species is named after the Latin name of Cádiz (*Gades*) from where the new form was discovered.

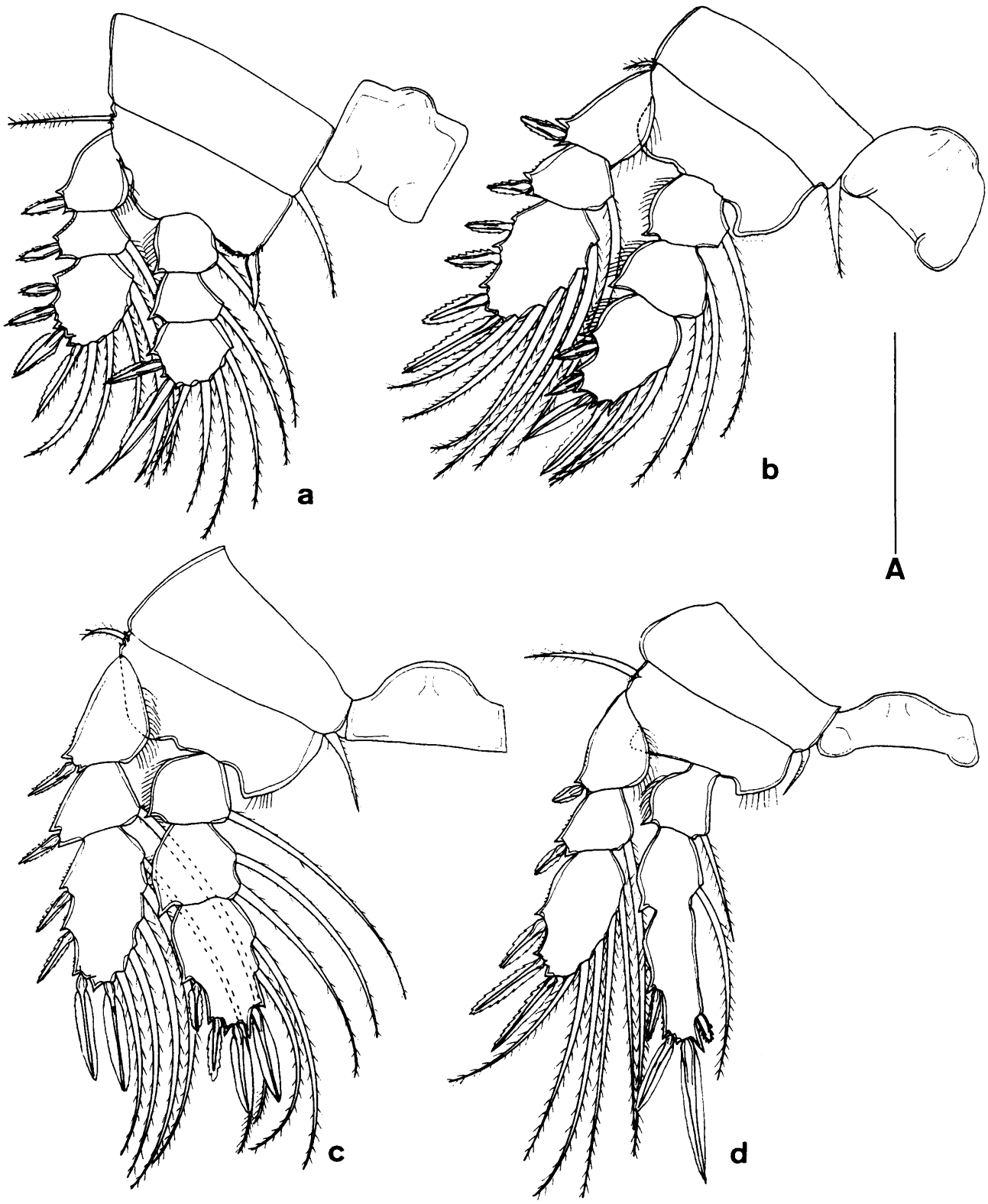

Fig. 3. *Fratia gaditana*, n. gen., n. sp. Female: a, leg 1 and intercoxal plate, anterior (A); b, leg 2 and intercoxal plate, anterior (A); c, leg 3 and intercoxal plate, anterior (A); d, leg 4 and intercoxal plate, anterior (A). Scale bar: A, 150 μm.

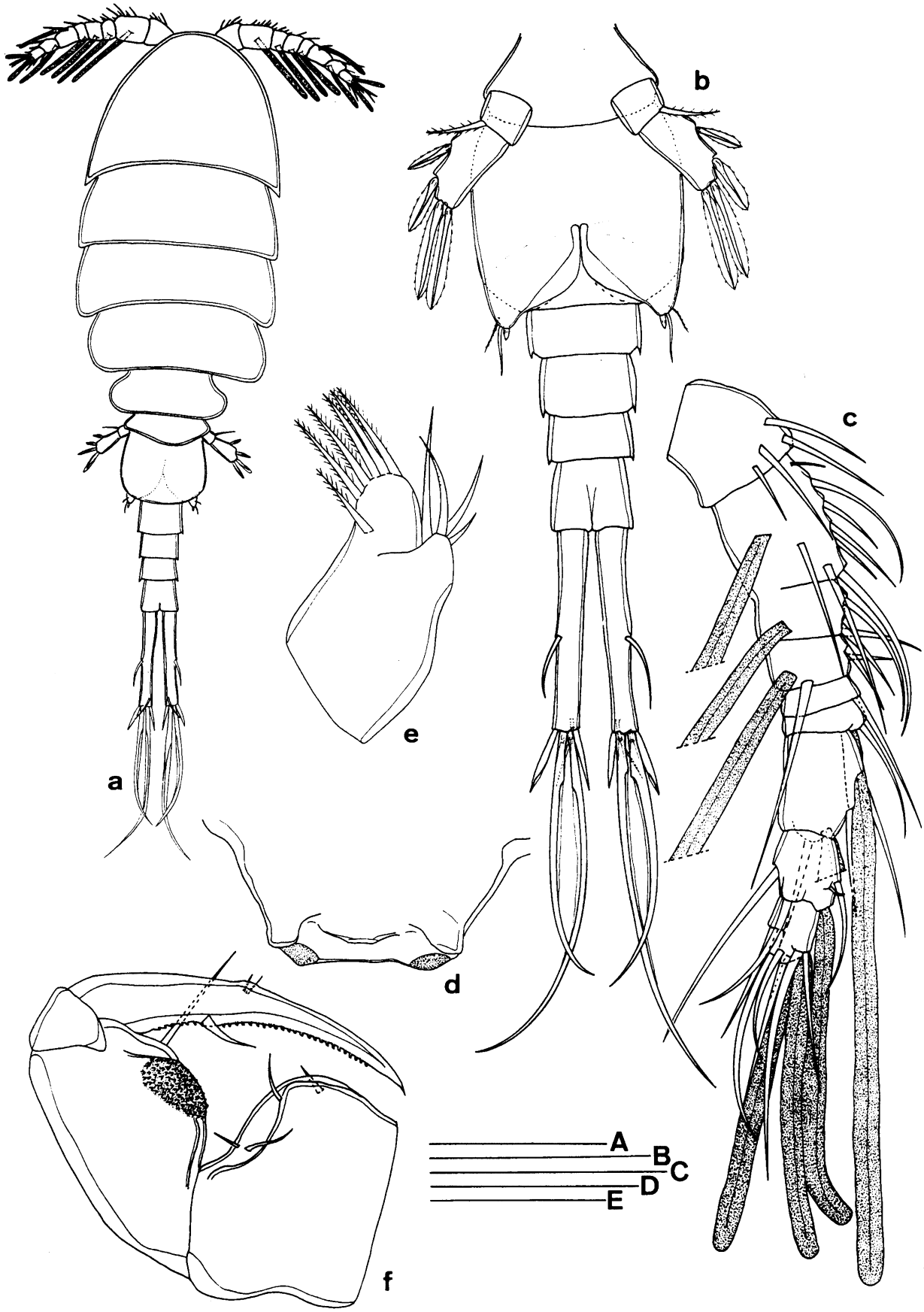

Fig. 4. *Fratia gaditana*, n. gen., n. sp. Male: a, dorsal (A); b, urosome, ventral (B); c, antennule, ventral (C); d, labrum, ventral (D); e, maxillule (E); f, maxilliped, ventral (D). Scale bars: A, 200 μm; B, 120 μm; C, 70 μm; D, 50 μm; E, 30 μm.

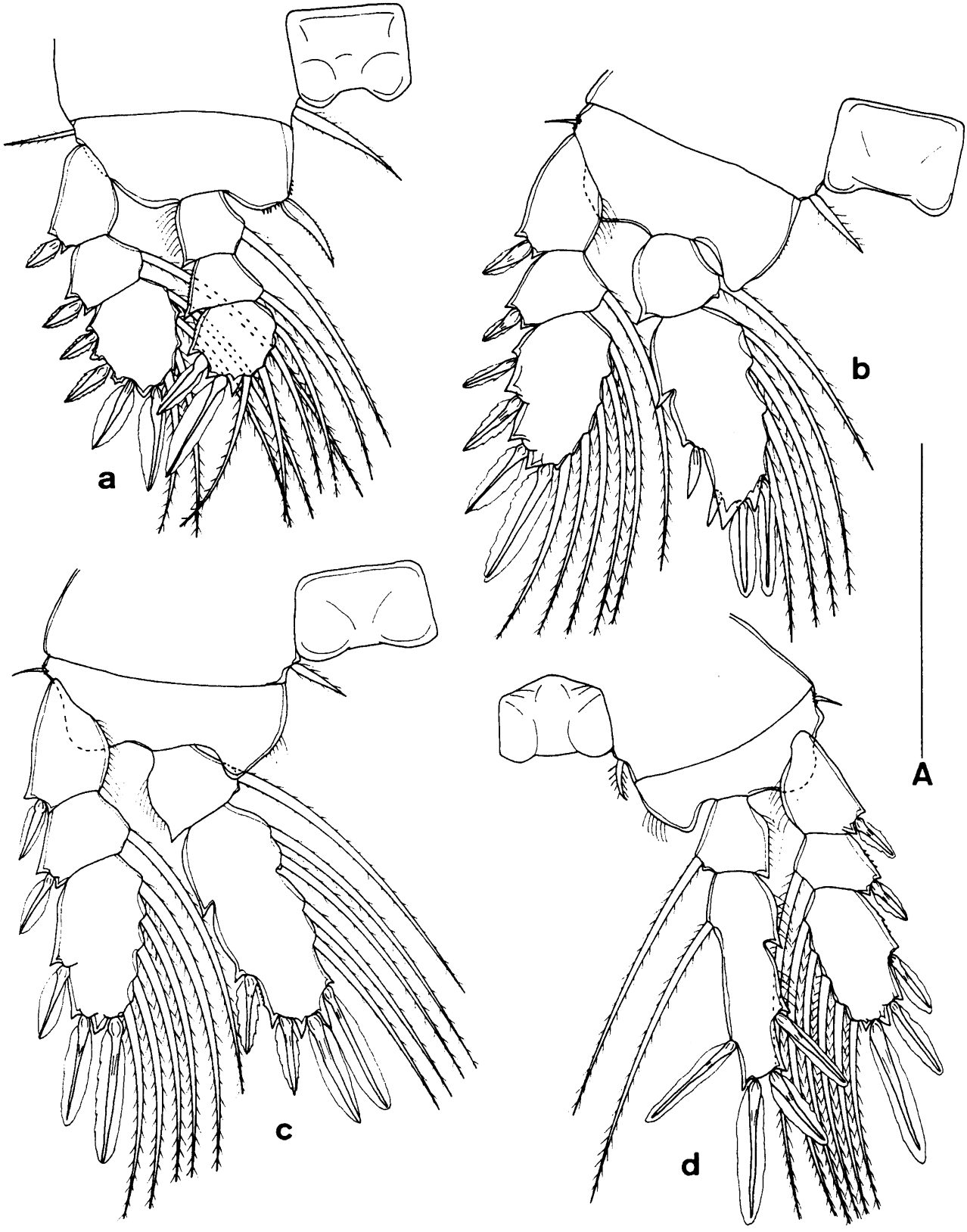

Fig. 5. *Fratia gaditana*, n. gen., n. sp. Male: a, leg 1 and intercoxal plate, ventral (A); b, leg 2 and intercoxal plate, anterior (A); c, leg 3 and intercoxal plate, anterior (A); d, leg 4 and intercoxal plate, anterior (A). Scale bar: A 100 μm.

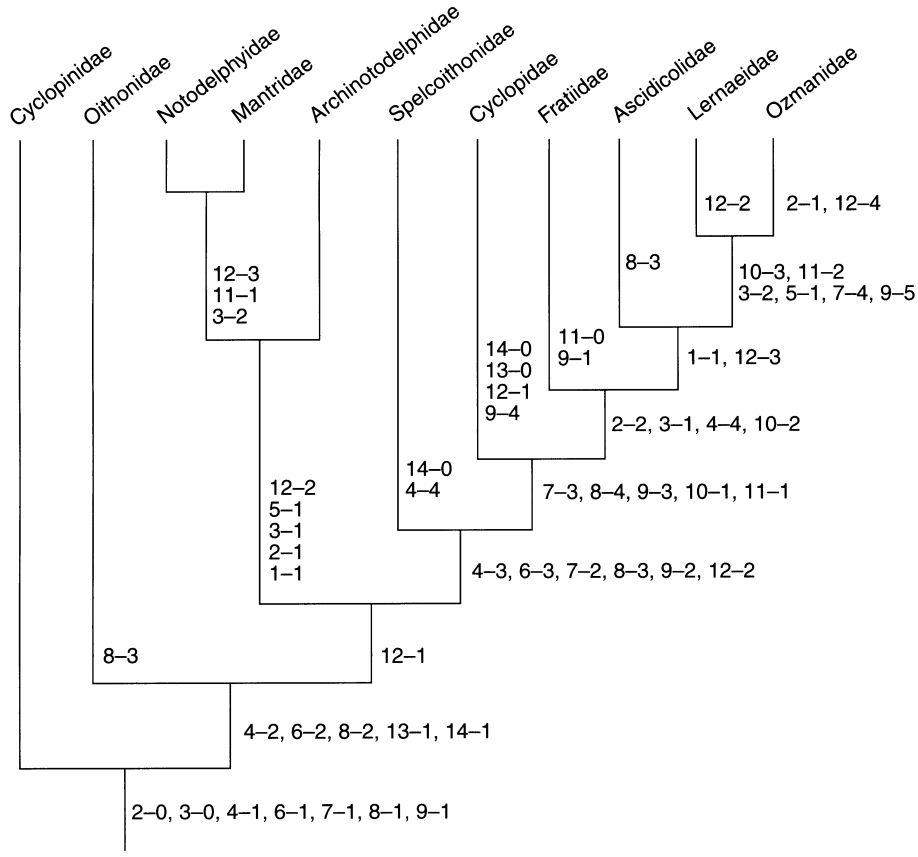

Fig. 6. Cladogram (phylogenetic tree) of cyclopoid families obtained by using HENNIG86 Version 1.5. For character codes see Table 2.

DISCUSSION

The new genus described above is remarkable in displaying a mixture of morphological features found in two copepod orders, the Cyclopoida and Poecilostomatoida. With a reduced mandibular palp in both sexes and the lack of a geniculate antennule in the male, *Fratia* can be considered as some primitive poecilostomatoids, particularly the Erebonasteridae. According to Huys & Boxshall (1991), the female genital system in erebonasterids is, unlike the rest of the poecilostomatoids (but just like the new genus and all cyclopoids), typical in consisting of a pair of laterally located gonopores (genital apertures) and a pair of midventrally located copulatory pores. Thus, it appears that *Fratia* is attributable to the Poecilostomatoida. However, the antennule of the new genus shows otherwise.

Huys & Boxshall (1991) indicated that poecilostomatoids are characteristic in having a pair of antennules with less than 7 segments in both sexes and that of the male antennule is typical in having the ancestral segments of XXIV through XXVIII fused into one (terminal) segment. Therefore, with an 8-segmented antennule in both sexes (see Figs 2a, 4c), *Fratia* is not attributable to the Poecilostomatoida, and, furthermore, the armature of 4+1 aesthete on the penultimate segment of *Fratia* indicates that it was derived from fusion of the ancestral XXIV and XXV, a feature that is unknown of the members of the Poecilostomatoida. Accordingly, the new genus is considered to be a member of the Cyclopoida.

Currently, three families of cyclopoid copepods are known to use ascidians as their hosts: Archinotodelphyidae, Ascidicolidae and Notodelphyidae. The first family is the least modified among these three groups with a typical cyclopoid body form (Monniot, 1990). As a symbiont of ascidians and displaying a cyclopiform type of body without carrying a brood sac, the new genus (*Fratia*) was first thought to be a member of the Archinotodephyidae, but close examination of the appendages did not support this. Except for the antenna which retains the ancestral form (of lacking a terminal hook), the rest of the cephalosoic appendages, viz. antennule, mandible, maxillule, maxilla and maxilliped, in the new genus are more specialized (reduced) than those found in the Archinotodelphyidae.

Comparisons with other less modified cyclopoids, like Cyclopidae, Cyclopinidae, Mantridae, Oithonidae, and Speleoithonidae, also showed that none of them can accommodate *Fratia*. The new genus cannot be placed in the Cyclopidae chiefly because of the differences in the antennule (the lack of a geniculation in the male) and mandible (with less reduced palp). It differs from the Cyclopinidae and Oithonidae in having a much

Table 1. Characters and character states used in the cladistic analysis of Cyclopoida, including the new family. Numbers in parentheses denote the numerical coding of the transformation of character states, based on Misophrioida as the outgroup

1	25th and 26th ancestral antennule segments separated (0), fused (1)
2	Male antennule with double geniculation (0), with distal geniculation only (1), without geniculation (2).
3	Basis of antenna with 2 inner setae (0), with 1 inner seta (1), without inner seta (2)
4	Exopod of antenna 7-segmented and with setae (0), reduced and represented by 3 setae (1), represented by 2 setae (2), represented by 1 seta (3), absent (4)
5	Inner terminal element of antennal endopod a seta (0), a hook (1)
6	Basis of mandibular palp with 3 inner setae (0), 2 inner setae (1), 1 inner seta (2), without seta (3)
7	Exopod of mandibular palp 5-segmented (0), 4-segmented (1), 2-segmented (2), reduced to a seta (3), absent (4)
8	Epipodite of maxillule represented by 8 setae (0), 3 setae (1), 2 setae (3), 1 seta (4), lost (5)
9	Exopod of maxillule with 11 setae (0), 4 setae (1), 3 setae (2), 2 setae (3), 1 seta (4), lost (5)
10	Maxilla endopod 3-segmented (0), 2-segmented (1), 1-segmented (2), lost (3)
11	Basis of maxilliped carrying 2 inner setae (0), 1 inner seta (1), no seta (2)
12	Endopod of maxilliped 5-segmented (0), 3-segmented (1), 2-segmented (2), 1-segmented (3), absent (4)
13	Coxa and basis of leg 5 separated (0), fused (1)
14	Intercoxal plate (sclerite) of leg 5 present (0), absent (1)

Table 2. Data matrix of 14 characters and their states in the cladistic analysis of Cyclopoida. The question mark (?) indicates an unknown state

Taxa	Characters													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Outgroup (Misophriidae)	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Archinotodelphyidae	1	1	1	2	1	2	1	2	1	0	0	2	1	1
Ascidicolidae	1	2	1	4	0	3	3	3	3	2	1	3	1	1
Cyclopidae	0	0	0	3	0	3	?	4	4	1	1	1	0	0
Cyclopinidae	0	0	0	1	0	1	1	1	1	0	0	0	0	0
Fratiidae	0	2	1	4	0	3	3	4	1	2	0	2	1	1
Lernaeidae	1	2	2	4	1	3	4	4	5	3	2	2	1	1
Mantridae	1	1	2	2	1	2	1	2	1	0	1	3	1	1
Notodelphyidae	1	1	2	2	1	2	1	2	1	0	1	3	1	1
Oithonidae	0	0	0	2	0	2	1	3	1	0	0	0	1	1
Ozmanidae	1	1	2	4	1	3	4	4	5	?	2	4	1	1
Speleoithonidae	0	0	0	4	0	3	2	3	2	0	0	2	1	0

more specialized antennule (with fewer number of segments), mandible (with reduced palp), maxilla (with reduced endites) and maxilliped (modified endopod with large claw); from the Mantridae by the possession of more specialized mandible, maxillule (with much reduced praecoxa and coxa) and maxilla, but more primitive antenna (lacking terminal claw); and from the Speleoithonidae in having a more specialized antennule, and less specialized mandible (bearing a reduced palp). Therefore, a new family, Fratiidae, is proposed to accommodate *Fratia* with the diagnosis for the family as in the genus given above.

A cladistic analysis was undertaken to elucidate the phylogenetic relationships of the new family with the other families in the Cyclopoida. The 14 characters selected by Ho (1994) in his analysis of the phylogeny of the Cyclopoida were adopted. The coding of these 14 selected characters is given in Table 1 and the data matrix for the outgroup (Misophrioida) and 11 families of the ingroup is given in Table 2.

The computer program HENNIG86 Version 1.5 (Farris, 1988) was used in the proposed cladistic analysis. The algorithm employed was ie* (implicit enumeration), which performs an exhaustive search to find all shortest trees. The analysis produced a single tree with a length of 59 steps, Consistency Index of 62, and Retention Index of 74. It is reproduced in Fig. 6.

The phylogenetic hypothesis shown in Fig. 6 indicates that the new family is allied more closely to the Ascidicolidae than to either the Archinotodelphyidae or the Notodelphyidae. The close affinity of the Fratiidae with the Ascidicolidae is shown in the sharing of character 2 (male antennule without geniculation), character 4 (antenna without exopod), character 6 (basis of mandibular palp without inner seta), character 7 (exopod of mandibular palp reduced to a seta), and character 10 (maxilla 1-segmented). However, due to having a separation between the ancestral antennal segments of XXV and XXVI (character 1) and a reduced maxillular epipodite (character 8, with 1 instead of 2 setae), coupled with the lesser reduction of the armature on the maxillular exopod (character 9, with 4 instead of 2 setae) and of the endopodal segment on the maxilliped (character 12, 2-segmented instead of 1-segmented), the Fratiidae is placed on a clade different from the Ascidicolidae.

In his analysis on the phylogeny of the cyclopoid families, Ho (1994) concluded that parasitism occurred twice in the history of cyclopoid evolution with both 'events' involving the ascidians. The first 'attempt' gave rise to the Notodelphyidae and Archinotodelphyidae, in

addition to the Mantridae (bivalve parasites), and the second 'attempt' led to the development of the ascidicolous copepods first before invasion of fresh-water regime to live as endoparasites in snails (Ozmanidae) or as ectoparasites on fish (Lernaeidae). This evolutionary scenario still holds true even with the addition of the Fratiidae to the Cyclopoida.

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