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Caenidae of Taiwan (Ephemeroptera)

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ABSTRACT

The nymphal stages of seven new species of Caenidae, all belonging to genus *Caenis*, from Taiwan have been described. They are *C. argillosa* n.sp., *C. nitida* n. sp., *C. bella* n. sp., *C. corphulenta* n. sp., *C. cornigera* n. sp., *C. granifera* n. sp., and *C. montana* n. sp. In addition, the eggs of six species were observed using scanning electron microscopy. Key to the species is given.
Key words: Caenidae, *Caenis*, nymph, egg, Taiwan.

臺灣的細蜉科(蜉蝣目)

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摘　要

本文描述台灣的細蜉科種類，共 7 新種，全部屬於 *Caenis* 屬，分別為：*C. argillosa* n.sp., *C. nitida* n.sp., *C. bella* n.sp., *C. corpulenta* n.sp., *C. cornigera* n.sp., *C. granifera* n.sp. 及 *C. montana* n.sp.。種類的判別均根據稚蟲特徵。其中 6 種的卵經用掃描式電子顯微鏡觀察與描述。文中附種的檢索表。
關鍵詞：細蜉科，*Caenis*，稚蟲，卵，台灣。

Introduction

The widespread family Caenidae was very poorly known in Taiwan and its neighboring areas (Thomas and Sartori, 1989; Ulmer, 1939–1940), and only nymphs of a few unnamed species were described (Ho and Hsu, 1977; Uéno, 1928; Yang et al. 1980). Yet, European species have been extensively reviewed by Malzacher (1976; 1984), who also provided a detailed description of the eggs (Malzacher, 1982).

We have collected seven species belonging to one genus of this family, and descriptions based on the nymphal and egg specimens have been made. In addition, the eggs of six species were examined using scanning electron microscopy.

While the mouth part of this nymphal specimens is of little use in classification, the surface structures such as setae, granules and other fine structures of tergites and operculate gills are very useful. Each operculate gill has a Y-shaped ridge, thus dividing the surface of operculate gill into three parts in the description as shown in Fig. 1–I.

Egg morphology is distinct among the collected species and thus offers useful classification characteristics this group. All egg materials used in this work were obtained from mature female nymphs (with black wing pads).

All holotypes of the following named species have been deposited in the collection of Department of Entomology, National Chung-Hsing University (NCHU), Taichung, Taiwan. Part of the paratypes have been deposited in the collection of National Museum of Natural Science (NMNS), Taichung, Taiwan.

Key to the species of *Caenis* of Taiwan (for nymph only)

1. Mesonotum without blunt process near anterolateral corner (Figs. 1–A, 2–A, 3–A, 4–A) ····· 2
   - Mesonotum with a blunt process near anterolateral corner (Figs. 5–A, 6–A, 7–A) ····· 5
2. Dorsum of head pale or light yellow and without any markings between eyes (Fig. 2–A); lateral margins of abdominal segment IX without any setae (Fig. 2–L) ····· *C. nitida* n.sp.
   - Dorsum of head with markings between eyes (Figs. 1–A, 3–A, 4–A); lateral margins of abdominal segment IX with setae ····· 3
3. Surface of forewing pads and operculate gills with long and short biforked setae (Figs. 4–I, J); forefemur with a longitudinal row of stout biforked acute setae (Fig. 4–F) ····· *C. corpulenta* n.sp.
   - Surface of forewing pads and operculate gills without biforked setae; forefemur with a longitudinal row of stout biforked clavate (Figs. 1–F, 3–F) ····· 4
4. When abdominal segment X be removed, dorsum of sternum IX with granules near posterior margin (Fig. 1–L); pedicel with about 10 pinnate setae near mesal margin (Fig. 1–E); outer posterolateral margin of operculate gills with acute setae (Fig. 1–A) ····· *C. argillosa* n.sp.
   - Dorsum of abdominal sternum IX not as above (Fig. 3–L); pedicel with 3–6 acute setae near mesal margin (Fig. 3–E); outer posterolateral margin of operculate gills without acute setae (Fig. 3–K) ····· *C. bella* n.sp.
5. Surface of forewing pads and operculate gills with triangular scales (Fig. 5–J); median area of middle and hind femora with stout biforked clavate setae (Figs. 5–G, H) ··· *C. cornigera* n.sp.
   - Surface of forewing pads and operculate gills with round granules (Figs. 6–I, 7–I, 12); median area of middle and hind femora with long acute setae (Fig. 6–G) or seta absent (Fig. 7–G, H) ····· 6
6. Operculate gills pale, distal half brown and divided into 2 parts (Fig. 6–A); middle and hind femora with long acute

setae (Fig. 6-G); lateral margins of operculate gills without fine biforked setae (Fig. 6-J) ····· *C. granifera* n.sp.

- Operculate gills uniform brown, paler near posterior and lateral margins (Fig. 7-A); middle and hind femora with few fine setae (Fig. 7-G, H); outer lateral margins of operculate gills with fine biforked setae (Fig. 7-K) ····· ····· *C. montana* n.sp.

***Caenis argillosa* Kang & Yang n.sp.**
(Figs. 1, 8, 16)

Mature nymphs: body length, female 2.99–4.25 mm, male 2.59–3.20 mm.

Head: dorsum brown, pale between antennae; with faint pale markings and numerous small pale spots between eyes. Pedicel with about 10 pinnate setae near mesal margins. Mandibles: basal half of dorsum, rough, with biforked pinnate setae near lateral margins.

Thorax: mesonotum brown with faint stripes; surface of forewing pad with triangular scales sparsely. Forelegs: femur 2.12–2.43 times as long as wide, with a longitudinal row of biforked clavate setae medially; basal half of femur with fine biforked setae near anterior margin; distal half of posterior margin of femur with stout, long biforked setae; distal half of femur with blunt triangular scales, basal half smooth; tibia 0.79–0.87 times length of femur; tarsus 0.55–0.63 times length of femur; mesal margin of claw smooth, without any denticles.

Abdomen: tergites VII–X pale, darkish medially except tergite X, basal half of tergite X darkish. Abdominal segments III–IX each with posterolateral projections and acute or clavate setae on lateral margin; projections of segments IV–VI larger than in other segments; each posterior margin of tergites II, IX and X with blunt dentate, on segment VII and VIII with long and short acute setae alternately; posterior margin of sternum IX with biforked setae, when removed abdominal segment X, dorsum can find a lot of granules near posterior margin. Operculate gills: brown, apical 1/4 pale to light brown; each fringe with long and short acute setae alternately except anterior margin; posterolateral margin and inner ridge with a few biforked clavate setae; dorsum with blunt triangular scales sparsely and covered with dirt normally.

Eggs (Fig. 16): general shape oblong, with a large polar cap on one pole; polar cap composed of conglomerate filaments, terminal of each filament intumescent, oval; chorionic surface porous or alveolar; a transversal, zonal micropyle on subequatorial area.

Holotype: female mature nymph, Peikang, Kuohsing, Nantou Hsien, Taiwan, (310 m), 22-XI-1991, S.C. Kang, in NCHU.

Paratypes (mature nymph): 6♂♂, 20♀♀, same data as for holotype. 3♂♂, 14♀♀, in NCHU; 3♂♂, 6♀♀, in NMNS.

Other mature nymphal specimens examined: 5♂♂, 8♀♀, Shuangchi, Taipei Hsien, 31-V-1991, S.C. Kang & H. C. Chang; 4♂♂, 6♀♀, Yehyu, Lanhsu, Taitung Hsien, 29-VII-1991, H.C. Chang; 6♂♂, 7♀♀, Hwesunlinchun, Lenai, Nantou Hsien, (750 m), 19-VIII-1991, H.C. Chang; 1♂, 9♀♀, Luku, Nantou Hsien, (600 m), 30-VIII-1991, S.C. Kang & H.C. Chang; 4♂♂, 3♀♀, Kueigo, Kuohsing, Nantou Hsien, 16-XI-1991, S.C. Kang; 9♀♀, Gutyulin, Kuohsing, Nantou Hsien, 16-XI-1991, S.C. Kang; 1♂, 13♀♀, Shuili, Nantou Hsien, (290 m), 18-XI-1991, S.C. Kang; 4♂♂, 3♀♀, Sinchungheng, Hsini, Nantou Hsien, (620 m), 18-XI-1991, S.C. Kang; 1♂, 20♀♀, Kuohsing, Nantou Hsien, (235 m), 22-XI-1991, S.C. Kang; 12♀♀, Weichuan, Liukuei, Kaohsiung Hsien, (235 m), 20-XII-1991, S.C. Kang; 3♂♂, 4♀♀, Hsinpu, Hsinchu Hsien, (120 m), 19-XI-1990, S.C. Kang; 5♂♂, 20♀♀, Peipu, Hsinchu Hsien, (190 m), 19-XI-1990, S.C. Kang; 3♂♂, 12♀♀, Chiasien, Kaohsiung Hsien, (145 m), 13-XII-1990, S.C. Kang; 7♂♂, 12♀♀, Shinlu, Shityu, Pintung Hsien, (205 m),

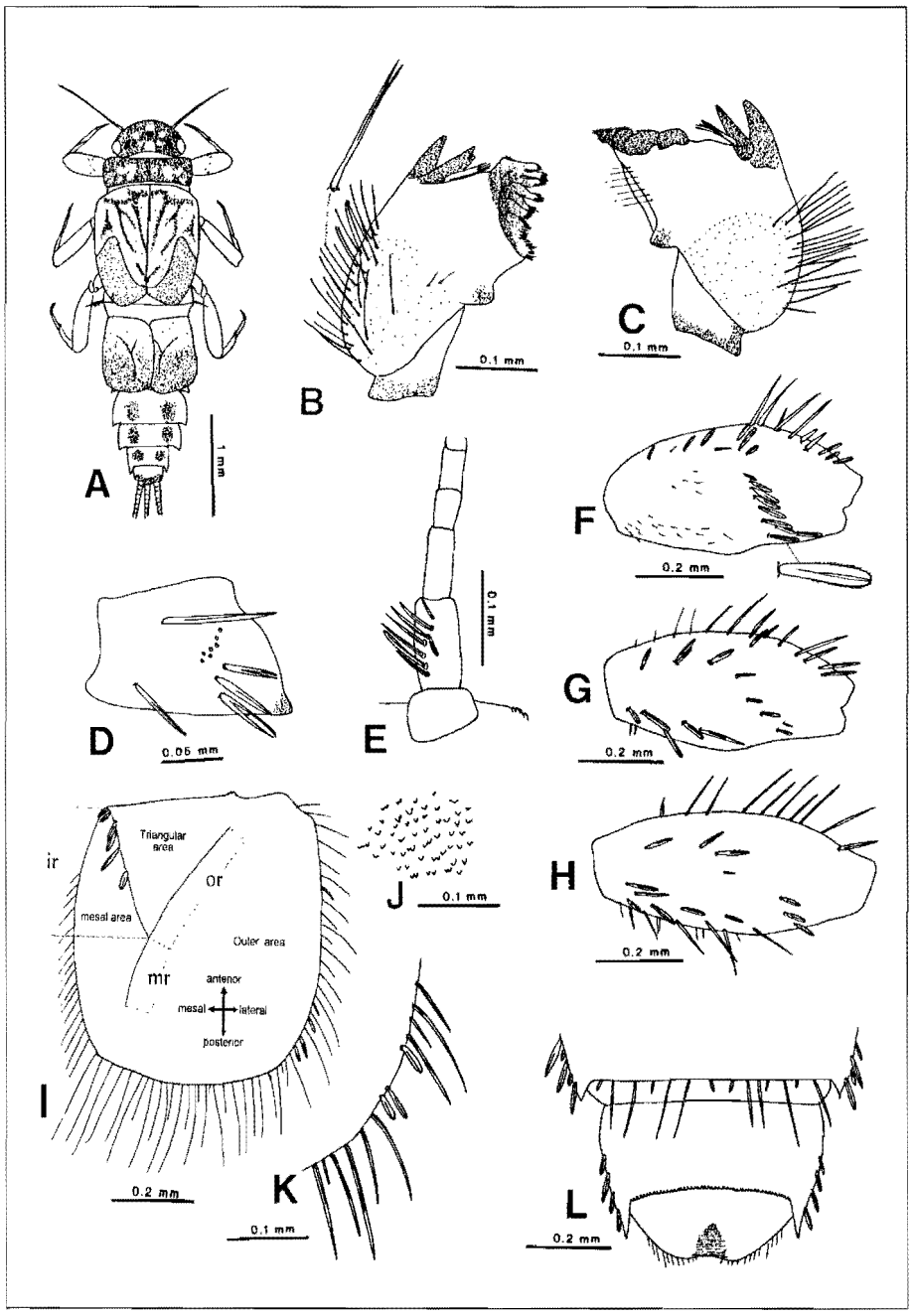


Fig. 1. Nymph of *Caenis argillosa* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; D, hind trochanter, dorsal; E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, hind femur, dorsal; I, right operculate gill(ir: inner ridge, or: outer ridge, mr: middle ridge); J, central surface of operculate gill; K, posterolateral margin of operculate gill; L, segments VIII and IX of abdomen (segment X been removed), dorsal.

17-XII-1990, S.C. Kang; 2♂♂, 4♀♀, Peinan, Taitung Hsien, 01-IV-1991, H.C. Chang; 3♂♂. 12♀♀, Hungtou, Lanhyu, Taitung Hsien, 03-IV-1991, H.C. Chang; 14♂♂, 12♀♀, Sani, Miaoli Hsien, (265 m), 19-IV-1991, S.C. Kang; 4♂♂, 8♀♀, Hungtou, Lanhsu, Taitung Hsien, 28-VII-1991, H.C. Chang; 4♂♂, 52♀♀, Hungtou Chungshinlong, Lanhsu, Taitung Hsien, 29-VII-1991, H.C. Chang; 3♂♂, 27♀♀, Langtao, Lanhsu, Taitung Hsien, 30-VII-1991, H.C. Chang; 7♀♀, Hontung, Juifang, Taipei Hsien, (120 m), 29-III-1992, S.C. Kang.

Distribution: Taiwan

Etymology: argillosa, L., feminine, meaning clayey.

Note: This new species resembles *Caenis nigropunctata* Ulmer 1939, but can be differentiated in nymphs by the following characters: (1) setae of lateral margins of mandibles are longer than in *C. nigropunctata*; (2) femora much wider; (3) mesal margin of fore tibia with long acute setae and a few biforked setae but *nigropunctata* only with fine biforked setae.

Caenis nitida Kang & Yang n.sp.

(Figs. 2, 9, 17)

Mature nymphs: body length, female 3.30–3.48 mm, male 2.76–3.20 mm.

Head: dorsum brown, uniform pale between eyes distinctly; pedicel with about 3 pinnate setae near mesal margins; gena with blunt scales. Mandibles: basal half of dorsum with blunt scales; lateral margins with long setae from middle to base; anterior margin of right mandible with a process between molar and incisors.

Thorax: mesonotum brown, darkish on lateral areas, paler on medial area, with a V-shaped marking medially; surface of forewing pads with triangular and M-shaped scales densely. Fore legs: femur 2.63–3.16 times as long as wide, distal 1/3 with a longitudinal row of biforked clavate setae; basal half of femur with fine biforked setae near anterior margin; distal half of posterior margin of femur with biforked clavate setae; distal 2/3 of femur with blunt scales densely, basal 1/3 smooth; tibia 0.79–0.87 times length of femur, with a row of acute setae along mesal margin; tarsus 0.58–0.60 times length of femur, with a row of short acute setae along mesal margin; mesal margin of claw smooth, with 3 small denticles near base.

Abdomen: tergites VII–IX pale, darkish on each side of middle line, tergite X brown. Abdominal segments III–IX with posterolateral projections, in segments V–VII larger than in other segments; each lateral margin of tergites III–VII with acute setae, tergite VIII with acute and clavate setae, tergite IX without any setae. Each posterior margin of tergites I, II, IX and X with regular blunt denticles, tergites VIII with discontinuous denticles; posterior margins of tergite VII with long acute setae, tergite VIII with long acute and clavate setae alternately. Operculate gills: uniform brown, fringe with long acute setae on posterolateral and posteromesal margins, with short acute setae on mesal margin and biforked clavate setae on posterolateral margin; Y-shaped ridge with biforked clavate setae along inner ridge; dorsum of operculate gill with triangular scales densely.

Eggs (Fig. 17): general shape columnar, with a large, hummocky polar cap; polar cap composed with conglomerate filaments, terminal of each filament intumescent, oval; chorionic surface rather smooth; sometimes with a long, longitudinal ridge from polar cap to another pole; a transversal, slender zonal micropyle on equatorial area.

Holotype: female mature nymph, Shuangchi, Taipei Hsien, Taiwan, (360 m), 30-V-1991, S.C. Kang & H.C. Chang, in NCHU.

Paratypes (mature nymph): 5♂♂,

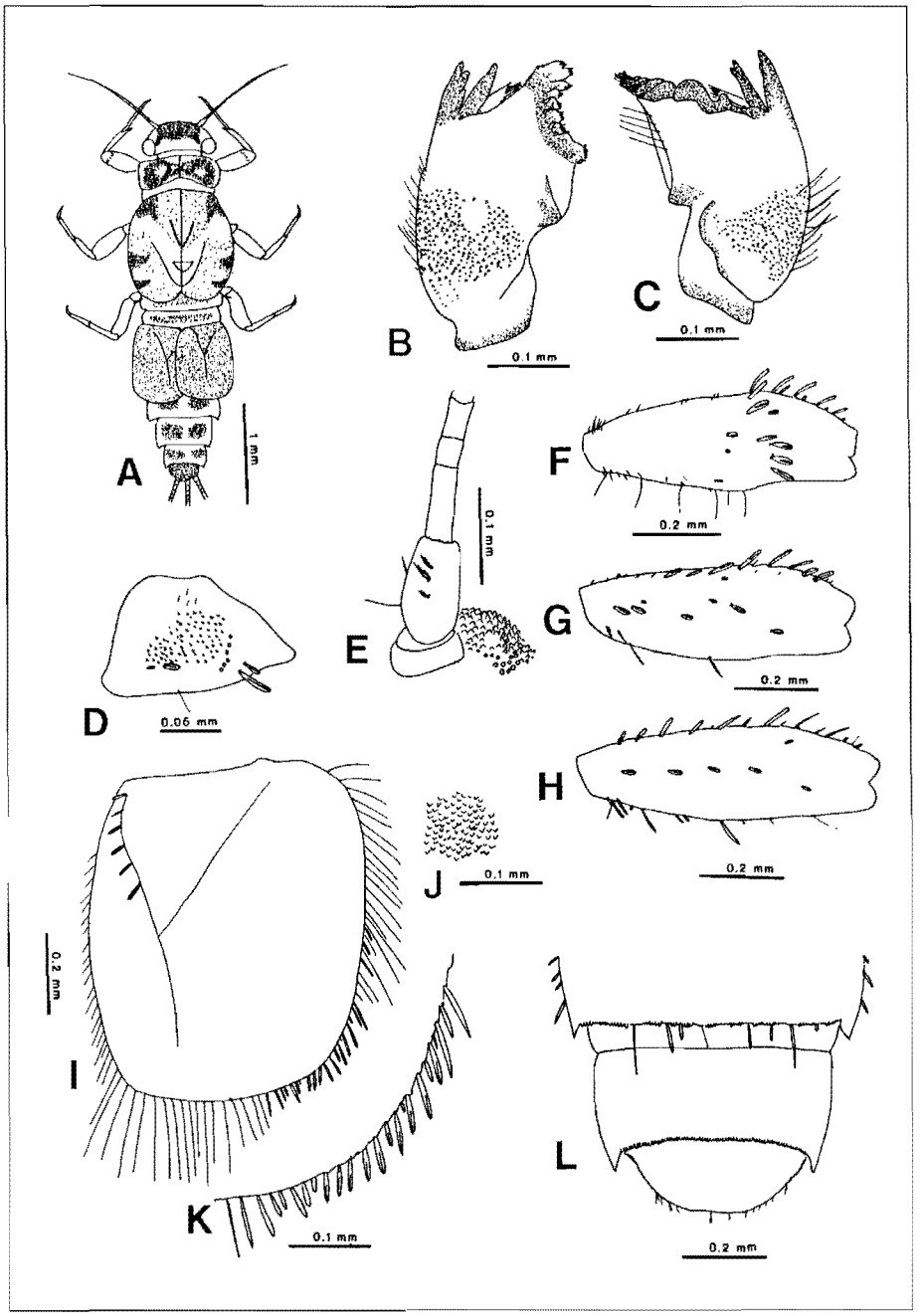


Fig. 2. Nymph of *Caenis nitida* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; D, hind trochanter, dorsal, E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, hind femur, dorsal; I, right operculate gill; J, central surface of operculate gill; K, posterolateral margin of operculate gill; L, segments VIII and IX of abdomen (segment X been removed), dorsal.

5♀♀, same data as for holotype; 1♂, 2♀♀, Shuangchi, Taipei Hsien, Taiwan, (450 m), 31-V-1991, S.C. Kang & H.C. Chang; 1♀, Peikang, Kuohsing, Nantou Hsien, Taiwan, (310 m), 22-XI-1991, S.C. Kang; 1♀, Kanchiao, Shuangchi, Taipei Hsien, Taiwan, (140 m), 28-III-1992, S.C. Kang. 4♂♂, 6♀♀, in NCHU; 2♂♂, 3♀♀, in NMNS.

Distribution: Taiwan

Etymology: nitida, L., feminine, meaning bright.

Note: This new species resembles *Caenis argillosa* n.sp., but can be differentiated in the nymphs by the following characters: (1) dorsum of head pale between eyes, without any markings; (2) setae of lateral margins of mandibles are shorter than in *C. argillosa*; (3) femora narrower than in *C. argillosa*; (4) surface of forewing pad with triangular and M-shaped scales densely; (5) operculate gills with biforked clavate setae on posterolateral margin, without long acute setae; (6) dorsum of operculate gill with dense triangular scales. In the egg, chorionic surface of this species is more smooth than *C. argillosa*.

Caenis bella Kang & Yang n.sp.
(Figs. 3, 10, 18)

Mature nymphs: body length, female 2.34–3.31 mm, male 2.30–3.10 mm.

Head: dorsum pale, with darkish stripes between eyes and antennae; pedicel with about 3–6 acute setae near mesal margin; gena with blunt scales near eyes. Mandibles: basal half of dorsum scatter with granules; lateral margins with long setae from middle to base; anterior margin of right mandible with a blunt process between molar and incisors.

Thorax: mesonotum brown with darkish markings near anterolateral corners; surface of forewing pads scatter with blunt scales uniformly. Fore legs: femur with faint darkish markings on distal half, 2.38–2.60 times as long as wide, with a longitudinal row of stout biforked clavate setae on distal 1/3; posterior margin with blunt biforked setae on distal half; distal half of femur with triangular scales, basal half smooth; tibia 0.85–0.89 times length of femur, with a row of biforked clavate setae along mesal margin; tarsus 0.58–0.60 times length of femur; mesal margin of claw smooth, without any denticles.

Abdomen: tergite VII with a pair of brown marking medially; tergites VIII–IX uniform brown, tergite X light brown, with 4 faint pale spots medially. Abdominal segments III–IX each with posterolateral projections, in segments V, VI each larger than in other segments; lateral margins of tergites IV–VI with long acute setae, tergite VII with long acute setae and a few biforked clavate setae, tergite IX with biforked clavate setae and a few long acute setae, tergite X only with short clavate setae. Posterior margins of tergites II, IX and X each with regular blunt serrate denticles, tergite VIII with a few discontinuous denticles; posterior margins of tergite VII, VIII both with long acute setae. Operculate gills: dark brown and with dark speckles, with a pale band along posterior and lateral margins distinctly; gill fringe with long and short acute setae except anterior margin, posterior setae is the longest; posterolateral margin with long and short clavate setae alternately; Y-shaped ridge with biforked clavate on inner ridge; dorsum of operculate gill with triangular scales, apex of scales somewhat blunt.

Eggs (Fig. 18): general shape columnar; chorionic surface with net-like grooves, each unit plate hexagonal, alveolar; a transversal, unclear, zonal micropyle on equatorial area, the opening round, large, clear.

Holotype: female mature nymph, Sanchan, Hsincheng, Hualien Hsien, Taiwan, (65 m), 03-IV-1991, S.C. Kang, in NCHU.

Paratypes (mature nymph): 1♂,

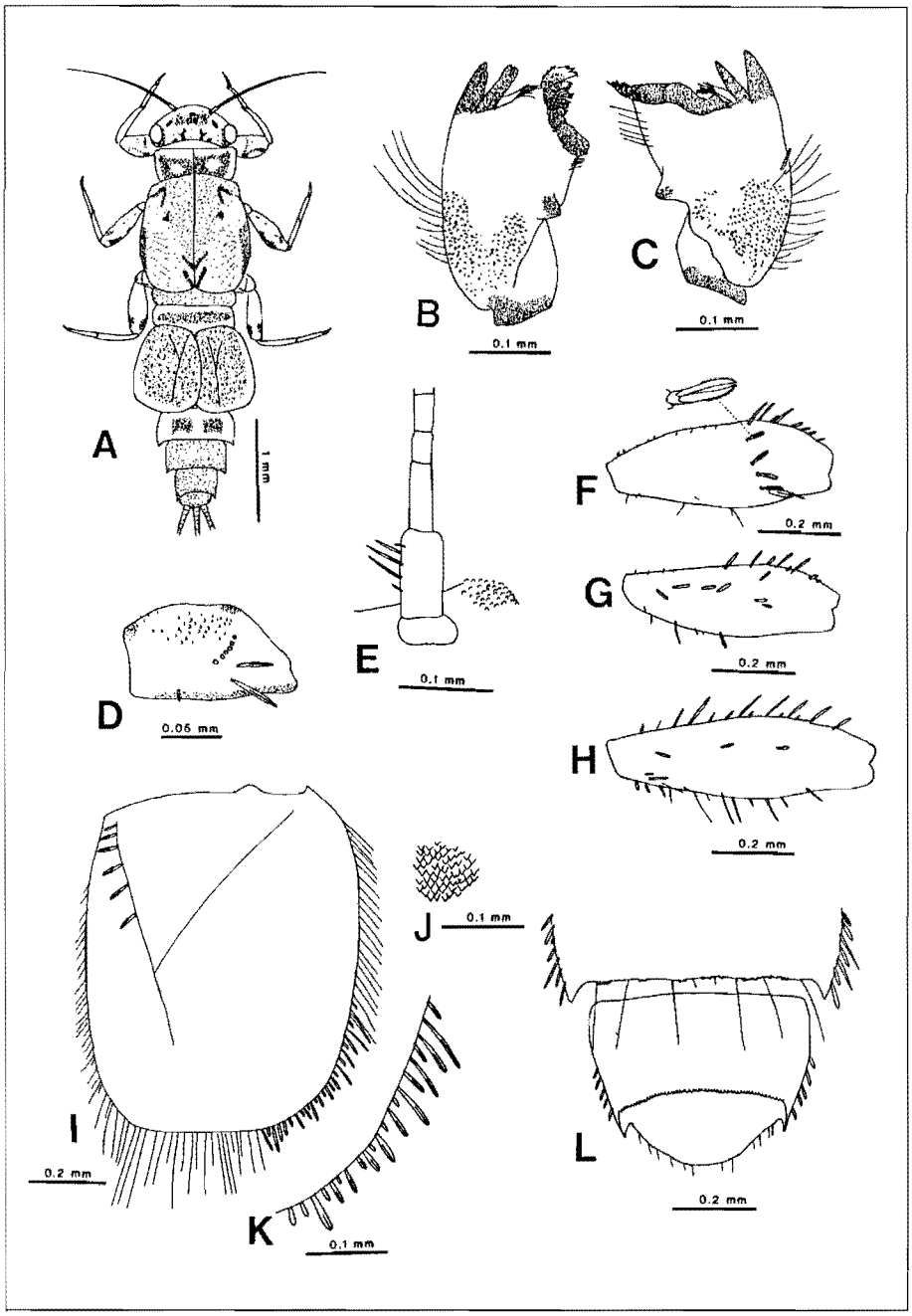


Fig. 3. Nymph of *Caenis bella* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; D, hind trochanter, dorsal; E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, hind femur, dorsal; I, right operculate qill; J, central surface of operculate gill; K, posterolateral margin of operculate gill; L, segments VIII and IX of abdomen(segment X been removed), dorsal.

8♀♀, same data as for holotype; 1♂, 6♀♀, Tona, Maolin, Kaohsiung Hsien, Taiwan, (335 m), 20-XII-1991, S.C. Kang; 3♂♂, 6♀♀, Kuolai-Kanchiao, Pinglin, Taipei Hsien, Taiwan, (365 m), 28-III-1992, S.C. Kang. 3♂♂, 16♀♀, in NCHU; 2♂♂, 4♀♀, in NMNS.

Other mature nymphal specimens examined: 2♂♂, 2♀♀, Maolin, Kaohsiung Hsien, 27-I-1990, S.C. Kang; 1♂, 2♀♀, Shanlinsi, Luku, Nantou Hsien, 22-VIII-1991, S.C. Kang & H.C. Chang; 3♂♂, 5♀♀, Alishan, Chiai Hsien, (710 m), 19-XI-1991, S.C. Kang; 1♂, 7♀♀, Shanping, Liukuei, Kaohsiung Hsien, (515 m), 19-XII-1991, S.C. Kang.

Distribution: Taiwan

Etymology: bella, L., feminine, meaning pretty.

Note: This new species resembles *Caenis nitida* n.sp., but can be differentiated in nymphs by the following characters: (1) dorsum of head with darkish stripes between eyes; (2) setae of lateral margin of left mandible longer than in *C. nitida*; (3) operculate gills dark brown and with dark speckles, margins with a distinct pale band along posterior and lateral margins; (4) lateral margin of tergite IX with biforked clavate setae and a few long acute setae. In eggs, they are different clearly: the chorionic surface of this species has net-like grooves while that of *C. nitida* is smooth. The chorionic structure resembles that of European species *C. robusta* Eaton (egg described by Malzacher, 1982): both have similar net-like grooves.

Caenis corpulenta Kang & Yang n.sp.
(Figs. 4, 11)

Mature nymphs: body length, female 4.10-4.45 mm, male 3.01-3.42 mm.

Head: dorsum pale, with darkish stripes between eyes and antennae; pedicel with about 5 acute setae near mesal margin and several short biforked pinnate setae on dorsum; gena with blunt scales on anterior margin.

Mandibles: basal half of dorsum with blunt scales and several biforked setae; lateral margins of right mandible with acute setae from middle to base; anterior margin with a blunt process between molar and incisors.

Thorax: mesonotum brown with darkish markings on lateral areas, with pale stripes on median area; surface of forewing pads with wide and narrow granular band alternately, in the narrow band with short biforked pinnate setae. Fore legs: femur 2.72-2.77 times as long as wide, with a longitudinal row of stout biforked acute setae on distal 1/3; basal half of femur with fine biforked setae near anterior margin, posterior margin and median area; distal half of femur with triangular scales, basal half smooth; tibia 0.81-0.85 times length of femur, with granules on lateral margin sparsely; tarsus 0.58-0.63 times length of femur; mesal margin of claw with 4-6 small denticles near base.

Abdomen: tergites VII-IX pale, tergite X light brown; tergite VII darkish on anteromedian margin and with a pair of markings near posterior margin; tergites VIII, IX each with a pair of brown markings medially. Abdominal segments III-IX each with posterolateral projections, in segments V-VI larger than in other segments; lateral margins of tergites III-VII each with acute setae, tergite VIII with acute and biforked setae, tergite IX only with small biforked setae. Posterior margins of tergites I, II, IX and X each with regular blunt denticles, tergites VIII with discontinuous denticles sparsely; posterior margins of tergite VII, VIII each with long acute and long biforked clavate setae, tergite II with long acute setae sparsely. Operculate gills: uniform light brown, fringe with long acute setae except anterior margin; posterolateral margin with biforked clavate setae; Y-shaped ridge with biforked clavate and acute setae on inner and middle ridges;

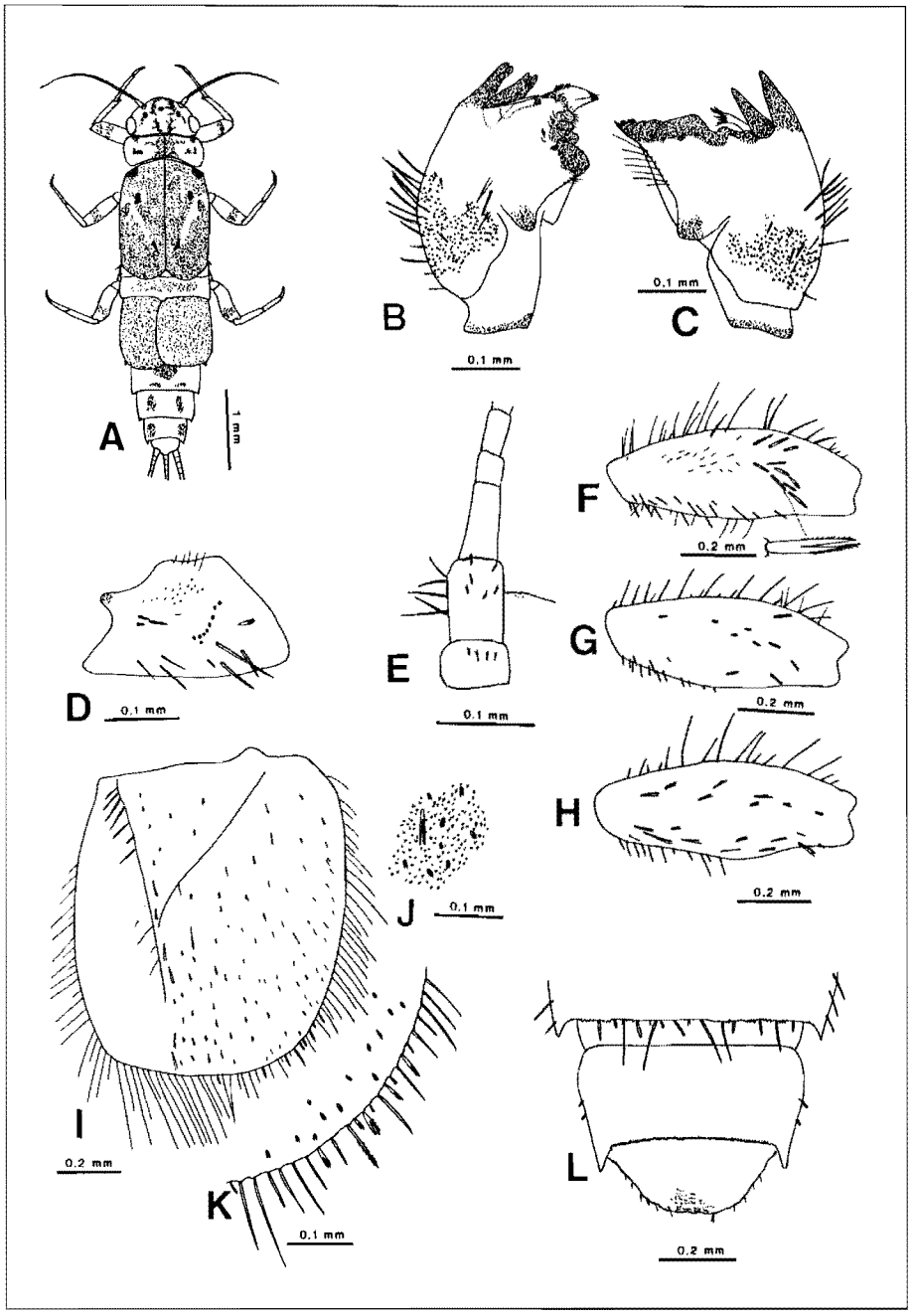


Fig. 4. Nymph of *Caenis corpulenta* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; d, hind trochanter, dorsal; E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, hind femur, dorsal; I, right operculate gill; J, central surface of operculate gill; K, posterolateral margin of operculate gill; L, segments VIII and IX of abdomen(segment X been removed), dorsal.

triangular and lateral areas with fine, acute scales sparsely and with long and short biforked setae, setae increase the number toward posterolateral margin.

Holotype: female mature nymph, Pinglin, Tsaotun, Nantou Hsien, Taiwan, (190 m), 16-XI-1991, S.C. Kang, in NCHU.

Paratypes (mature nymph): 4♂♂, 3♀♀, same data as for holotype; 2♀♀, Tsaotun, Nantou Hsien, Taiwan, (190 m), 20-VIII-1991, S.C. Kang & H.C. Chang; 3♂♂, 4♀♀, Tungtou, Chushan, Nantou Hsien, Taiwan, (120 m), 27-VII-1993, S.C. Kang. 5♂♂, 6♀♀, in NCHU; 2♂♂, 3♀♀, in NMNS.

Distribution: Taiwan

Etymology: corpulenta, L., feminine, meaning fat, stout.

Note: This new species resembles *C. argillosa* n.sp., but can be differentiated in nymphs by the following characters: (1) basal half of dorsum of mandibles with blunt scales; (2) surface of forewing pad with wide and narrow granular band alternately, in narrow band with short biforked pinnate setae; (3) apex of clavate setae of femora acute; (4) lateral and triangular area of operculate gill with long and short biforked setae.

***Caenis cornigera* Kang & Yang n.sp.**
(Figs. 5, 19)

Mature nymphs: body length, female 4.42–4.54 mm, male 3.33–3.74 mm.

Head: dorsum with darkish stripes between ocelli; vertex light yellow between eyes and with a pale oblong area on epicranial stem; pedicel with about 3–6 pinnate setae near mesal margins; gena with blunt scales near eyes. Mandibles: basal half of dorsum scatter with granules near lateral margins; lateral margins with long setae from middle to base; anterior margin of right mandible with a blunt process between molar and incisors.

Thorax: mesonotum yellow, with darkish markings and a process near anterolateral corner; surface of forewing pads with wide and narrow granular bands alternately; each narrow band composed of 2–3 rows of bigger granules, each wide band composed of 5–10 rows of smaller granules. Fore legs: femur with faint darkish markings on distal half, 2.88–3.00 times as long as wide, with a longitudinal row of stout biforked clavate setae on distal 1/3; posterior margin with blunt biforked setae on distal half; distal half of femur with triangular scales, basal half smooth; tibia 0.80–0.84 times length of femur, with a row of acute setae along mesal margin; tarsus 0.58 times length of femur; mesal margin of claw smooth, with 3–4 small blunt denticles near base.

Abdomen: tergites VII, VIII each with 3 markings medially; tergites IX with 2 pairs of markings medially, tergite X light brown. Abdominal segments III–IX each with posterolateral projections, in segments IV, V larger than in other segments; lateral margins of tergites IV–VI each with long acute setae, tergite VII, VIII each with long acute and a few biforked clavate setae, tergite IX with biforked clavate setae and a few long acute setae, tergite X with a few clavate setae or without any setae. Posterior margins of tergites II, IX and X each with blunt serrate denticles, tergite VIII with a few discontinuous denticles; posterior margins of tergite VII, VIII each with long acute and biforked clavate setae, tergite X smooth, without any setae. Operculate gills: uniform light brown, fringe with long and short acute setae except anterior margin, setae of posterior margin longer than on lateral margin; posterolateral margin with long and short clavate setae alternately; Y-shaped ridge with biforked clavate on inner ridge; dorsum of operculate gill with acute triangular scales densely.

Eggs (Fig. 19): general shape oval, with a polar cap; diameter of polar cap about 2/3 as long as equatorial area; chorionic surface porous or alveolar, no

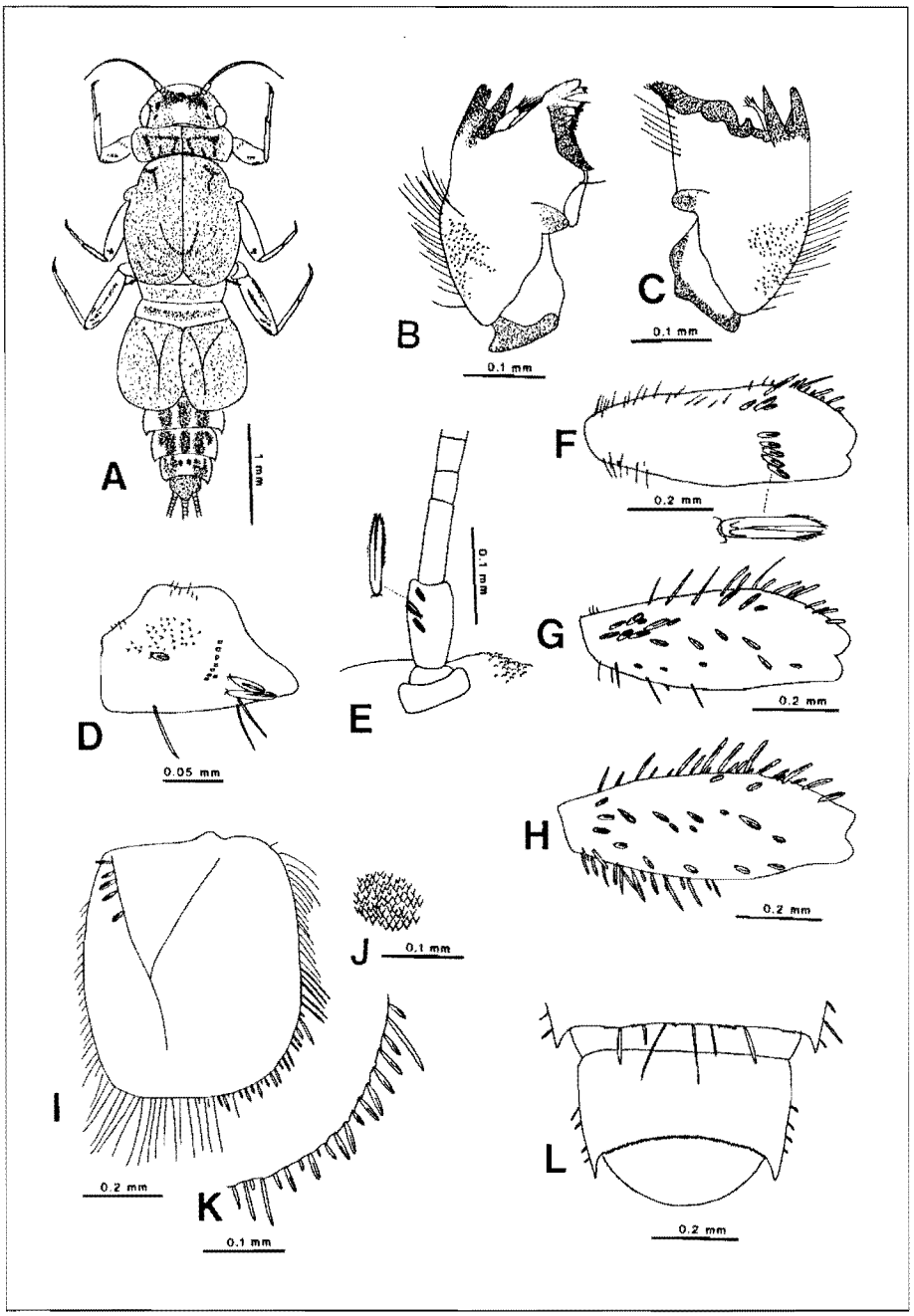


Fig. 5. Nymph of *Caenis cornigera* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; d, hind trochanter, dorsal; E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, hind femur, dorsal; I, right operculate gill; J, central surface of operculate gill; K, posterolateral margin of operculate gill; L, segments VIII and IX of abdomen(segment X been removed), dorsal.

visible micropyles or other structure.

Holotype: female mature nymph, Kanchiao, Shuangchi, Taipei Hsien, Taiwan, (140 m), 28-III-1992, S.C. Kang, in NCHU.

Paratypes (mature nymph): 11♂♂, 19♀♀, same data as for holotype. 8♂♂, 14♀♀, in NCHU; 3♂♂, 5♀♀, in NMNS.

Other mature nymphal specimens examined: 1♂, 1♀, Pali, Taipei Hsien, 16-XI-1990, S.C. Kang & H.C. Chang; 1♂, 7♀♀, Kuanhsi, Hsinchu Hsien, (460 m), 19-XI-1990, S.C. Kang; 2♂♂, 3♀♀, Taoyuan, Kaohsiung Hsien, (570 m), 13-XII-1990, S.C. Kang; 1♂, 4♀♀, Chinho, Taoyuan, Kaohsiung Hsien, (635 m), 02-IV-1991, S.C. Kang; 2♀♀, Pingsin, Shuangchi, Taipei Hsien, 31-V-1991, S.C. Kang & H.C. Chang; 7♀♀, Shanlinhsi-Hsitou, Chushan, Nantou Hsien, 22-VIII-1991, S.C. Kang & H.C. Chang; 1♀, Luku-Hsitou, Luku, Nantou Hsien, (1,040 m), 30-VIII-1991, S.C. Kang & H.C. Chang; 2♀♀, Hsitou-Shanlinhsi, Luku, Nantou Hsien, (1,010 m), 30-VIII-1991, S.C. Kang & H.C. Chang; 2♂♂, 4♀♀, Hontung, Juifang, Taipei Hsien, (120 m), 29-III-1992, S. C. Kang.

Distribution: Taiwan

Etymology: cornigera, L., feminine, meaning horned.

Note: This new species resembles *Caenis bella* n.sp., but can be differentiated in nymphs by the following characters: (1) mesonotum with a distinct process near anterolateral corner; (2) middle and hind femora with stout biforked clavated setae, and number of setae is more than in *C. bella*; (3) marking patterns of dorsum of head, thorax and abdominal different from those in *C. bella*.

Caenis granifera Kang & Yang n.sp.
(Figs. 6, 12, 13, 20)

Mature nymphs: body length female 3.04-3.32 mm, male 2.51-2.82 mm.

Head: dorsum brown, light brown on epicranial stem, pale on anterior area; all the surface of head with round granules densely; pedicel with 3-6 pinnate setae near mesal margin. Mandibles: basal half of dorsum with scales densely; lateral margins with long biforked setae medially; anterior margin of right mandible with a small blunt process between molar and incisors.

Thorax: mesonotum brown, with a V-shaped bright area near wing pads, all the surface with round granules except some striped area, anterolateral corner with a blunt process distinctly; surface of forewing pads with wide and narrow granular bands alternately; each narrow band composed of 2-3 rows of bigger granules, each wide band composed of 5-10 rows of smaller granules. Fore legs: femur 2.36-3.74 times as long as wide, with a longitudinal row of stout biforked clavate setae on distal 1/4, the setae fork about at apical 1/3 to 1/4; posterior margin with long setae on distal half; basal half of anterior area with fine biforked pinnate setae; distal half of femur with triangular scales, basal half smooth; tibia 0.73-0.78 times length of femur, with a row of long acute setae along mesal margin; tarsus 0.71-0.85 times length of femur; mesal margin of claw smooth, with 3-4 small blunt denticles near base.

Abdomen: tergite VII-X light brown, darkish laterally; abdominal segments II-IX each with posterolateral projections, in segment II blunt, in segments V, VI acute and larger than in other segments; lateral margins of tergites III-IX each with long acute setae; posterior margins of tergites II, IX and X each with blunt serrate denticles, tergite VIII with a few discontinuous denticles; posterior margins of tergite VII, VIII each with long acute setae, tergite X with fine branched setae. Operculate gills: pale, brown on middle of lateral and mesal area, light brown on middle of triangular area; fringe with long and short acute setae except anterior margin, on posterior margin longer

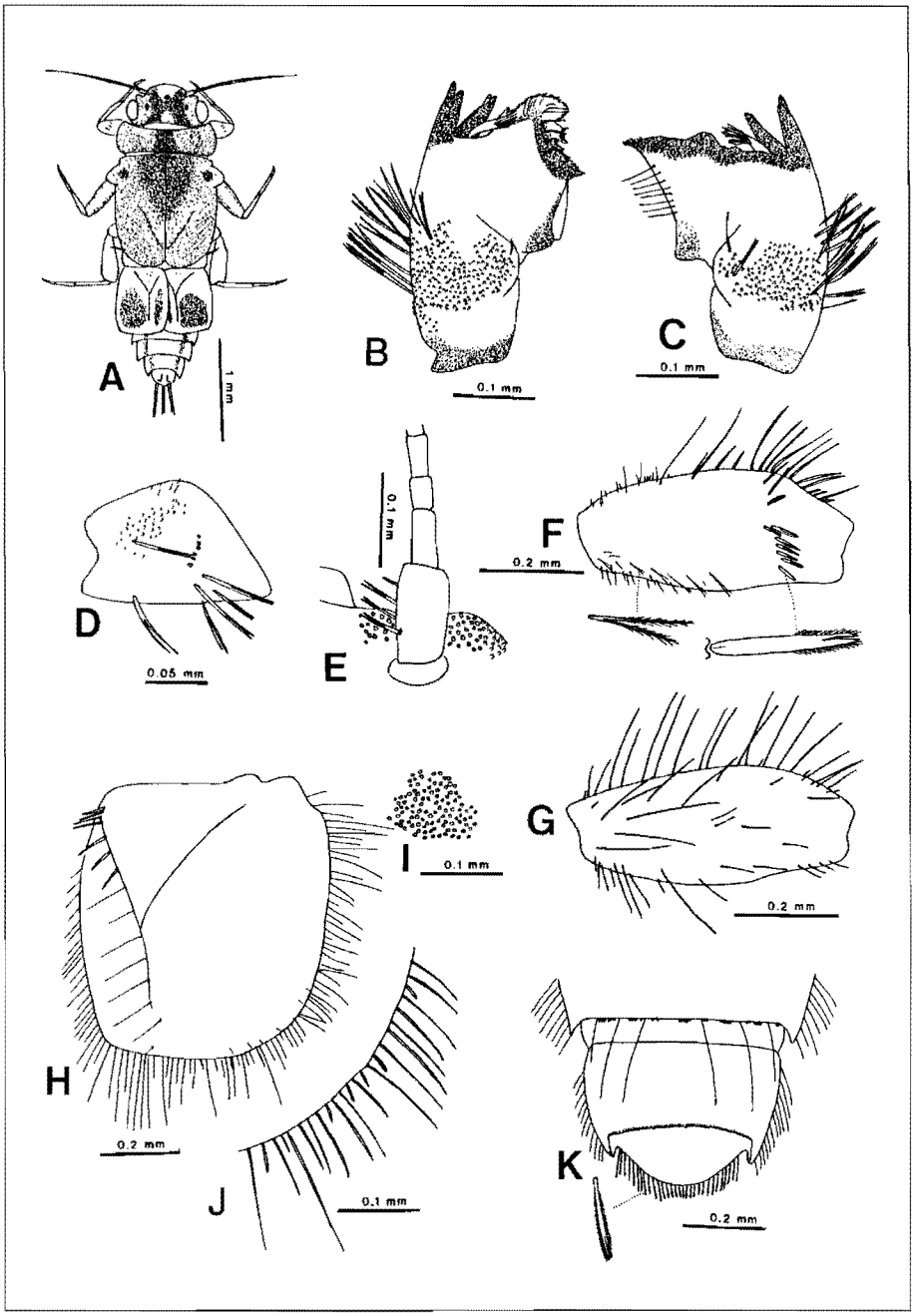


Fig. 6. Nymph of *Caenis granifera* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; D, hind trochanter, dorsal; e, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, right operculate gill; I, central surface of operculate gill; J, posterolateral margin of operculate gill; K, segments Ⅷ and Ⅸ of abdomen (segment x been removed), dorsal.

than on lateral margin; posterolateral margin with long and short fine setae alternately and mixed with a few small branched setae; Y-shaped ridge with biforked acute setae on inner ridge and long fine setae on middle ridge; dorsum of operculate gill with granules densely and flower-like microtrichiae, in which with a lot of pores (Fig. 13).

Eggs (Fig. 20): general shape long oval, with a large polar cap; diameter of polar cap slightly shorter than diameter of equatorial area; chorionic surface porous or alveolar, no visible micropyles or other structure.

Holotype: female mature nymph, Kanchiao, Shuangchi, Taipei Hsien, Taiwan, (140 m), 28-III-1992, S.C. Kang, in NCHU.

Paratypes (mature nymph): 8♂♂, 24♀♀, same data as for holotype. 6♂♂, 16♀♀, in NCHU; 2♂♂, 8♀♀, in NMNS.

Other mature nymphal specimens examined: 1♀, Kanchiao, Shuangchi, Taipei Hsien, 30-V-1991, S.C. Kang & H. C. Chang; 5♀♀, Pingsin, Shuangchi, Taipei Hsien, 31-V-1991, S.C. Kang & H. C. Chang; 2♀♀, Kanchi, Pinglin, Taipei Hsien, (365 m), 30-III-1992, S.C. Kang.

Distribution: Taiwan

Etymology: granifera, L., feminine, meaning grain-carrying.

Note: This new species resembles *Caenis argillosa* n.sp., but can be differentiated in the nymphs by the following characters: (1) the surface of head covered densely with round granules; (2) mesonotum with a blunt process near anterolateral corner (3) the middle and hind femur only with long acute setae and without biforked clavate setae; (4) posterior margin of tergite VIII only with long fine setae; (5) operculate gills pale, basal half brown; (6) surface of operculate gills with round granules densely, (7) Y-shaped ridge of operculate with long fine setae from middle to base; (8) posterolateral margins of operculate gills with long and short fine setae alternately; (9) lateral margin of abdominal segment IX with long numerous acute setae.

***Caenis montana* Kang & Yang n.sp.**
(Figs. 7, 14, 15, 21)

Mature nymphs: body length, female 3.90-4.30 mm, male 3.21-3.40 mm.

Head: dorsum dark brown, gena paler, light brown between eyes; all the surface of head with round granules densely; margin of gena convex strongly; pedicel with 3-6 small pinnate setae near mesal margin. Mandibles: basal half of dorsum with granules and scales densely; lateral margins with long fine setae medially.

Thorax: pronotum dark brown medially, pale on posteromedial and lateral margins; dorsal surface of thorax with round granules; anterolateral corner with a blunt process distinctly; surface of forewing pads with wide and narrow granular bands alternately; each narrow band composed of 1-5 rows of bigger granules, each wide band composed of 5-10 rows of smaller granules. Fore legs: femur 2.56-2.89 times as long as wide, with a longitudinal row of stout biforked clavate setae on distal 1/4, the setae fork slightly; posterior margin with long setae and long fine biforked setae on distal half; basal half of anterior area with fine biforked pinnate setae; dorsum of femur with acute triangular scales except basal of posterior area; tibia 0.81-0.84 times length of femur, with a row of long pinnate clavate setae and a row of acute setae along mesal margin, the branches of long pinnate clavate setae very fine; tarsus 0.71-0.85 times length of femur; mesal margin of claw smooth, with 3-5 small acute denticles near base.

Abdomen: tergite VII-X brown medially; tergite II, VIII-X and lateral areas of tergite VII with round granules densely; abdominal segments II-IX each with posterolateral projections, in segment II blunt, in segments VII acute and larger

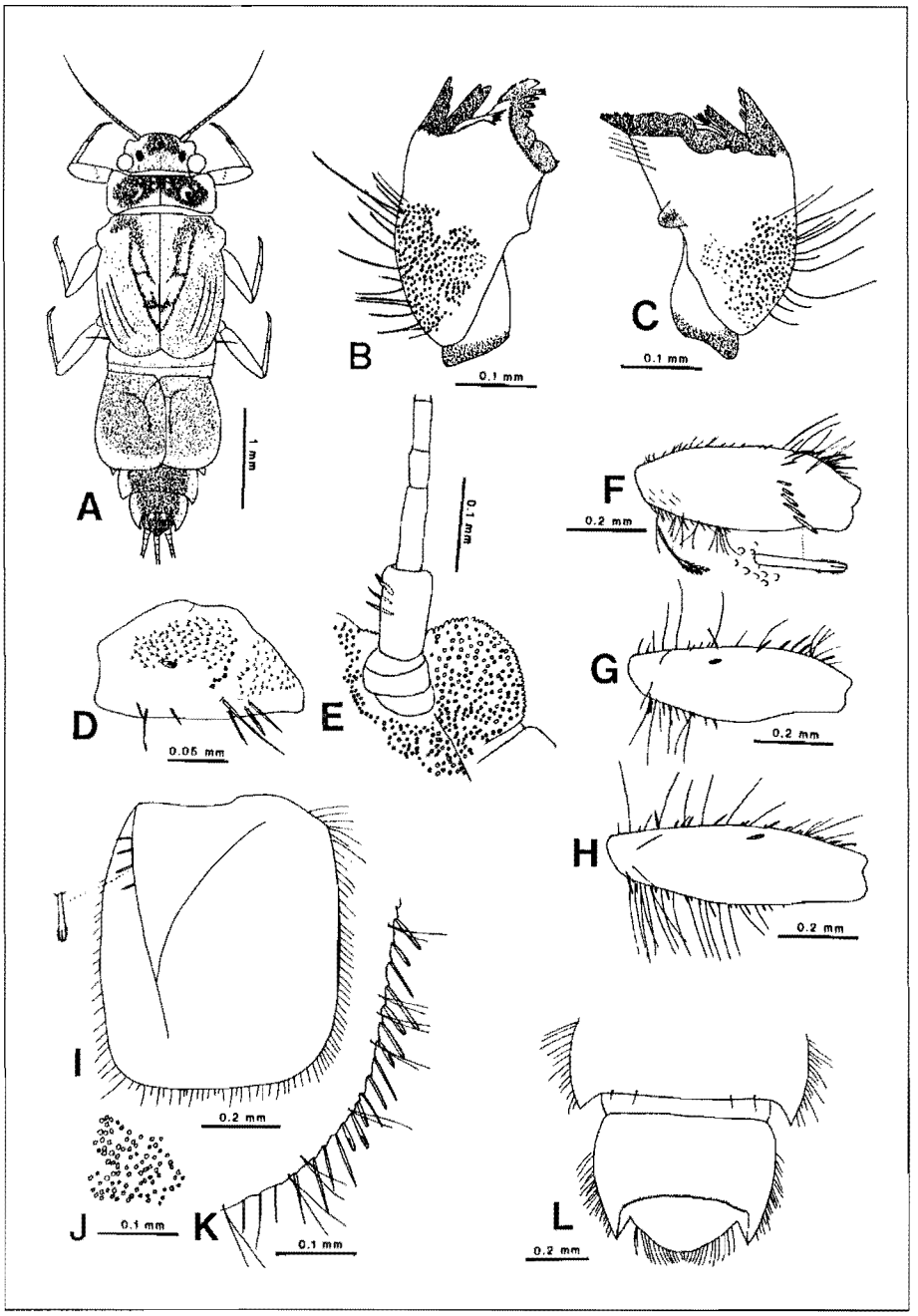
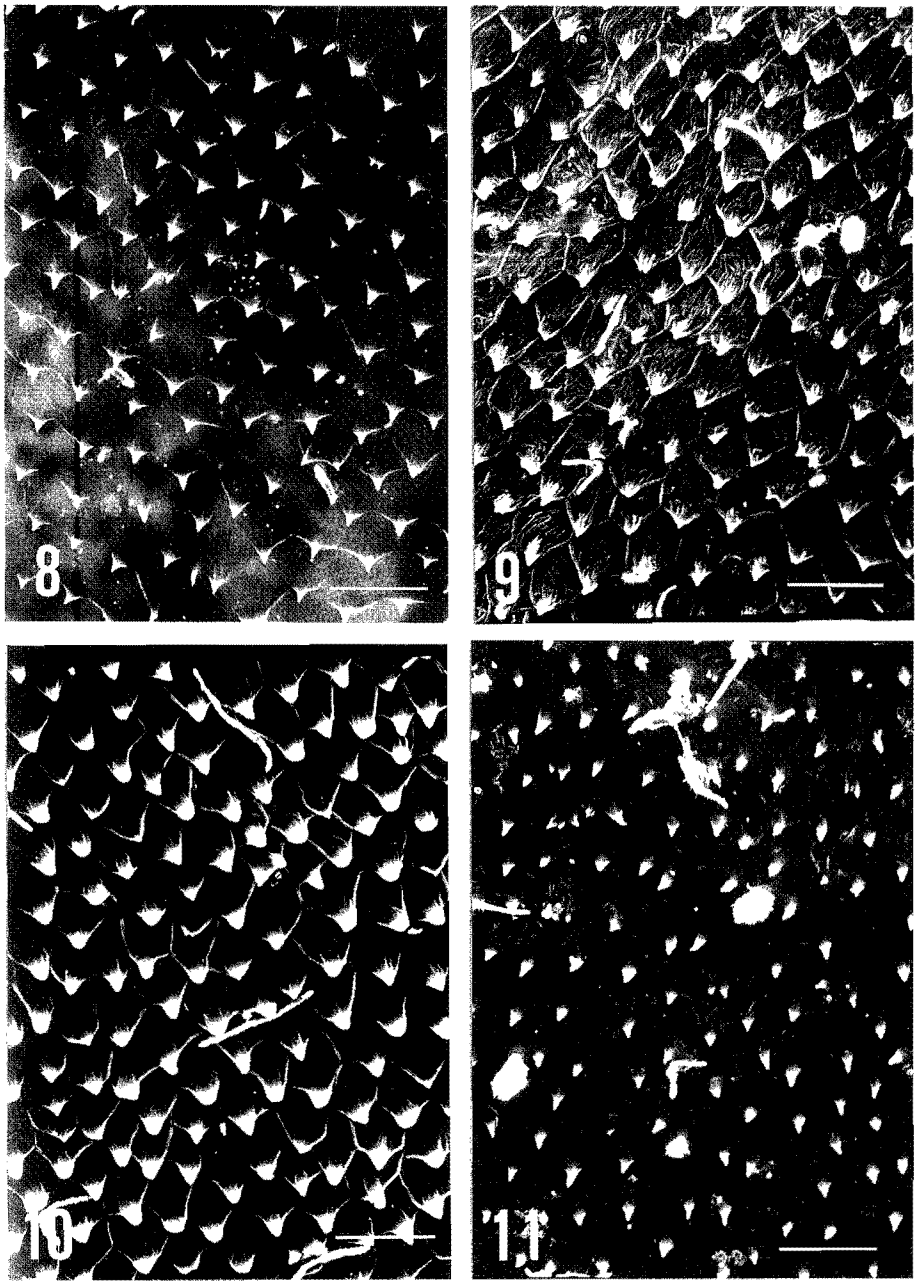
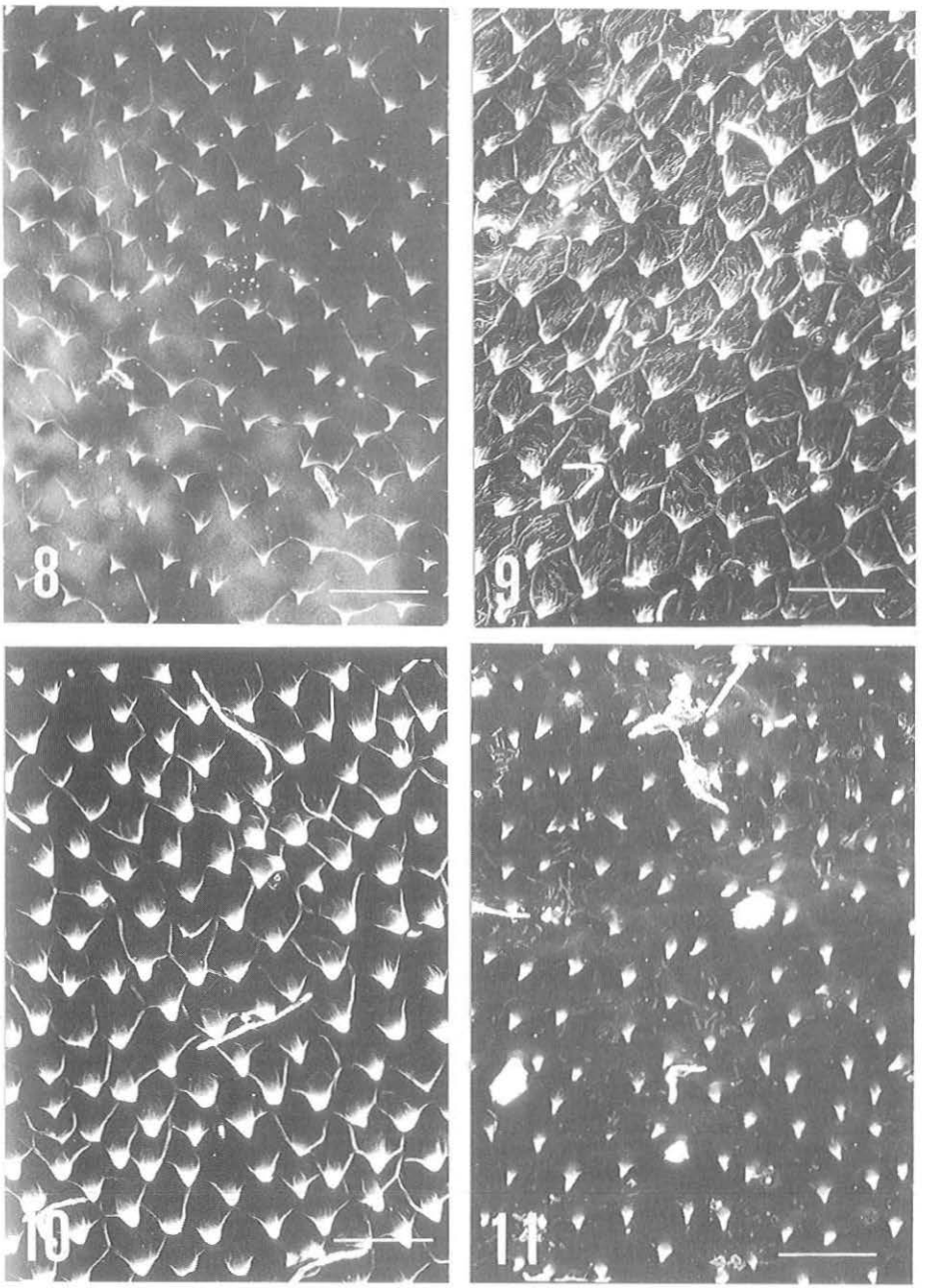


Fig. 7. Nymph of *Caenis montana* n.sp. A, dorsal; B, left mandible, dorsal; C, right mandible, dorsal; D, hind trochanter, dorsal; E, base of antenna and margin of gena, dorsal; F, fore femur, dorsal; G, middle femur, dorsal; H, Hind femur, dorsal; I, right operculate gill; J, central surface of operculate gill; K, outer posterolateral margin of operculate gill; L, segments VIII and Ix of abdomen (segment x been removed), dorsal.

than in other segments; lateral margins of tergites IV–VII each with long acute and long fine setae; tergites VIII, IX each with long acute and pinnate clavate setae; posterior margins of tergites IX with blunt serrate denticles, tergite X with acute denticles; posterior margins of tergite VII with long acute setae, tergite VII

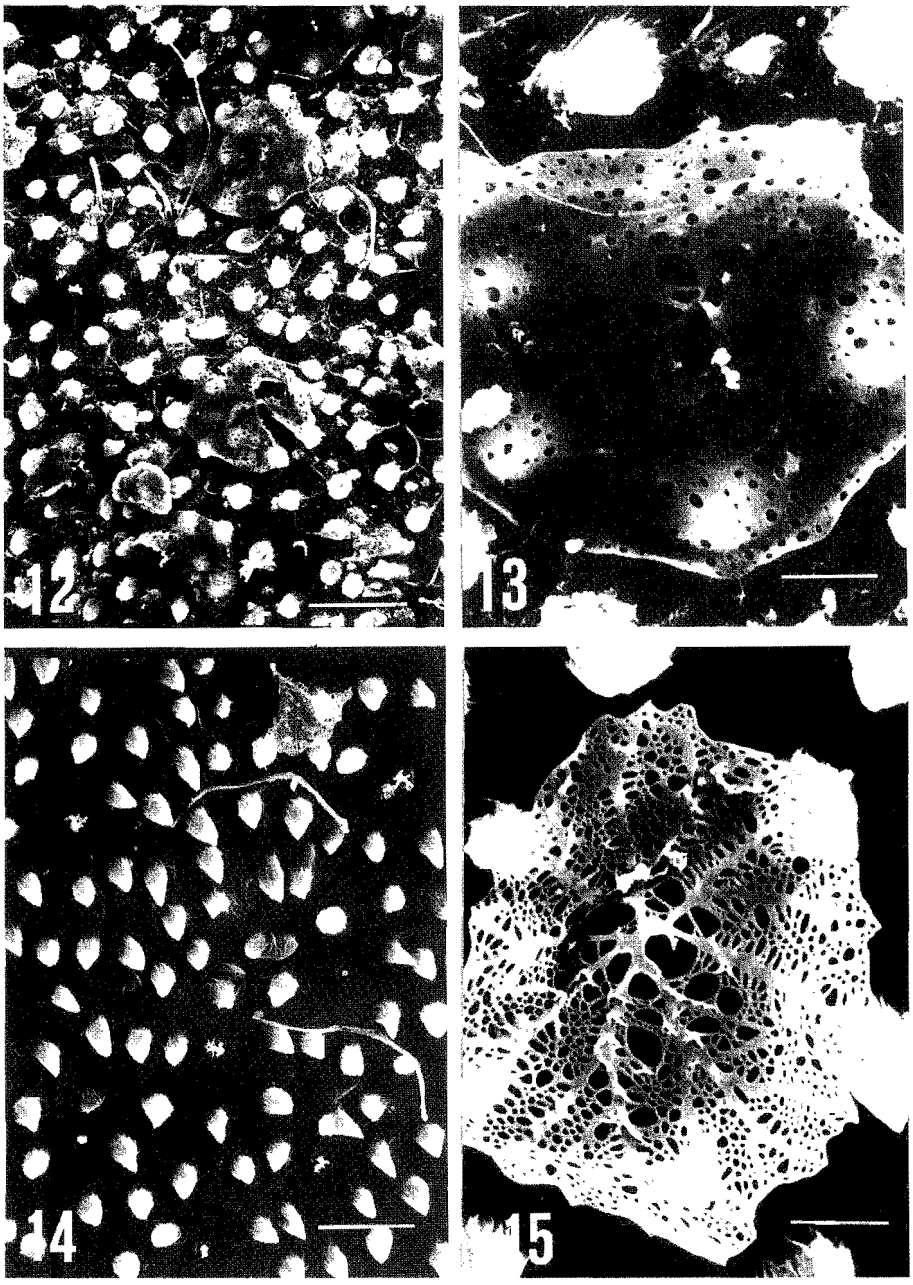


Figs. 8–11. Dorsum of operculate gill (medial area) of *Caenis* spp. 8, *C. argillosa* n.sp.; 9, *C. nitida* n.sp.; 10, *C. bella* n.sp.; 11, *C. corpulenta* n.sp. [each scale=20 μm].

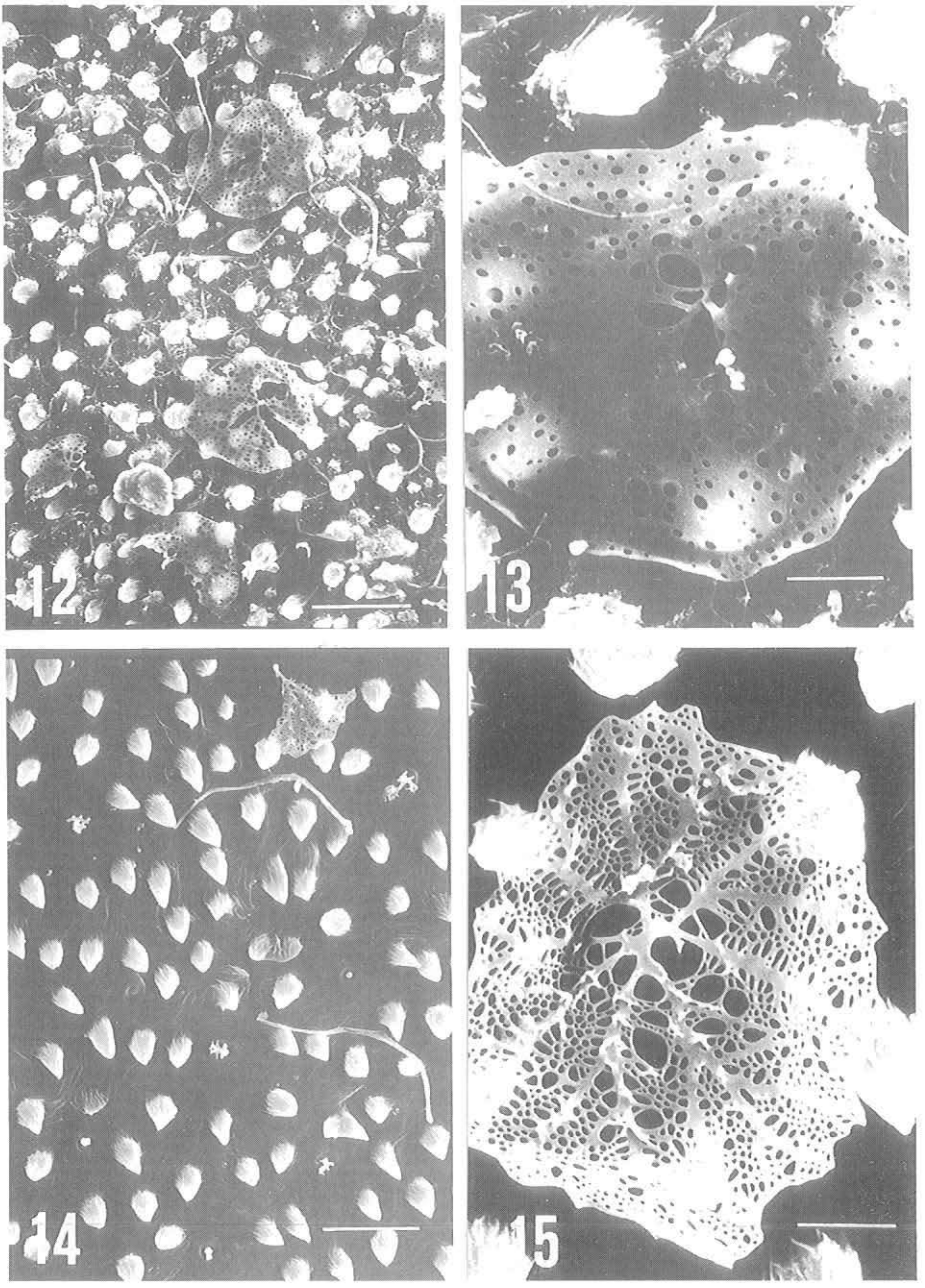


Figs. 8–11. Dorsum of operculate gill (medial area) of *Caenis* spp. 8, *C. argillosa* n.sp.; 9, *C. nitida* n.sp.; 10, *C. bella* n.sp.; 11, *C. corpulenta* n.sp. [each scale=20 μm]

with fine pinnate setae, tergite IX with fine branched setae. Operculate gills: uniform brown, paler on posterior and lateral margins; mesal margin with short acute setae, posterior margin with long and short fine acute setae alternately, lateral margin with clavate setae and a few fine biforked setae from posterior to



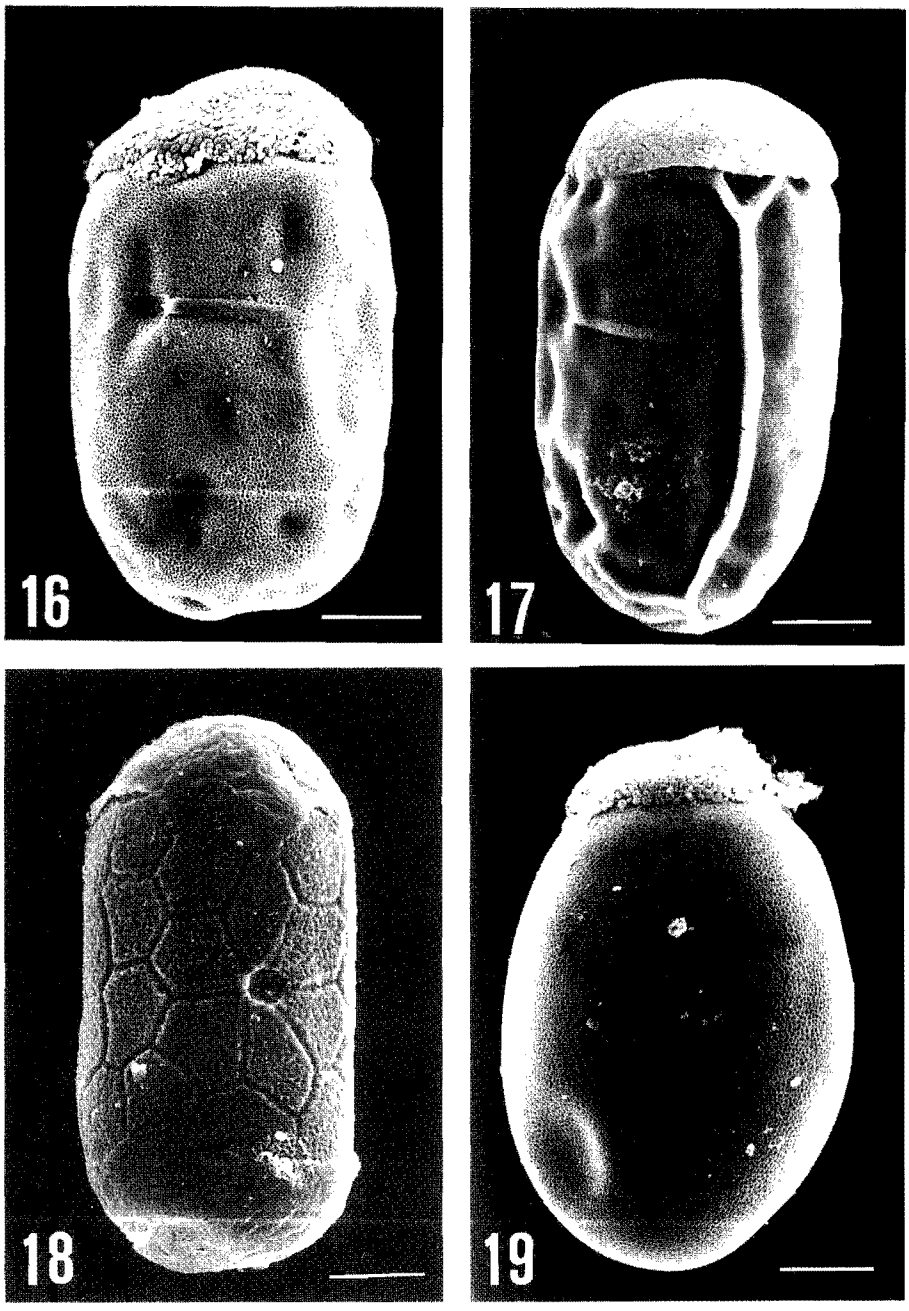
Figs. 12–15. Dorsum of operculate gill (medial area) of *Caenis* spp. 12–13, *C. granifera* n.sp.; 13, microtrichiae; 14–15, *C. montana* n.sp.; 15, microtrichiae. [scale: 12 and 14=20 μm; 13 and 15–5 μm].



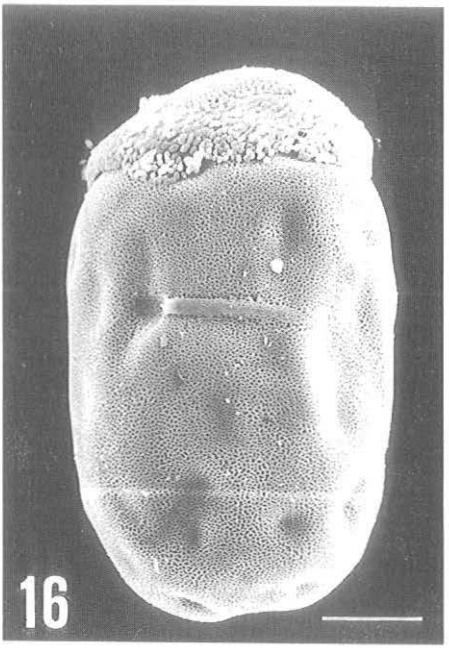
Figs. 12–15. Dorsum of operculate gill (medial area) of *Caenis* spp. 12–13, *C. granifera* n.sp.; 13, microtrichiae; 14–15, *C. montana* n.sp.; 15, microtrichiae. [scale: 12 and 14=20 μm; 13 and 15–5 μm].

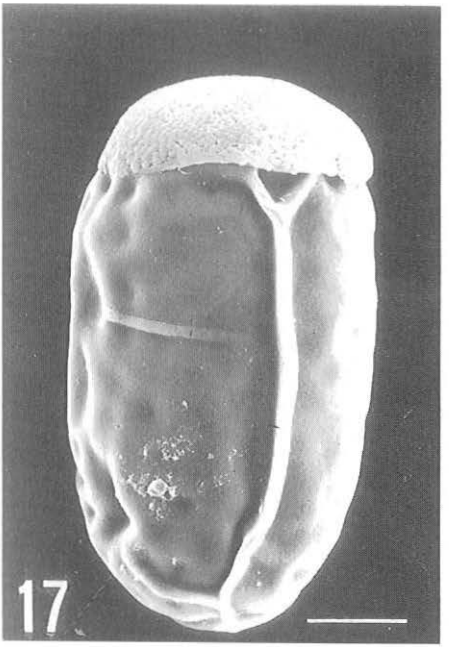
lateral margins; Y-shaped ridge with biforked pinnate clavate setae on inner ridge; dorsum of operculate gill with conical tubercles and coralloid microtrichiae.

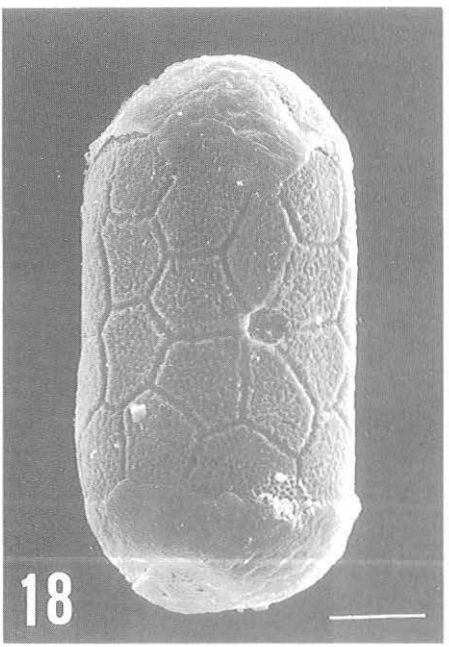
Eggs (Fig. 21): general shape long oval, with a large polar cap; diameter of polar cap slightly shorter than of

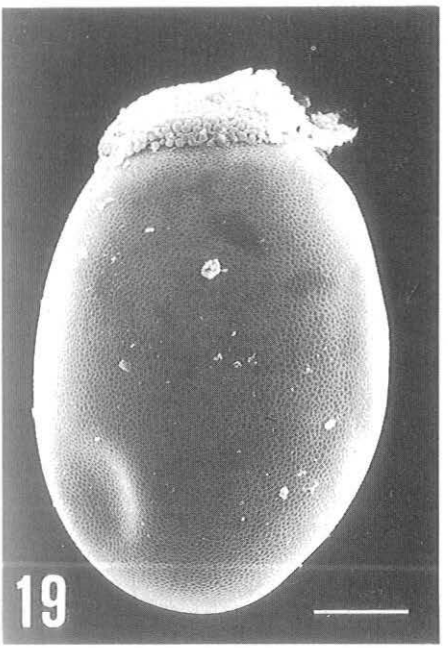


Figs. 16–19. Eggs. 16, *C. argillosa* n.sp.; 17, *C. nitida* n.sp.; 18, *C. bella* n.sp.; 19, *C. cornifera* n.sp. [each scale=20 μm].

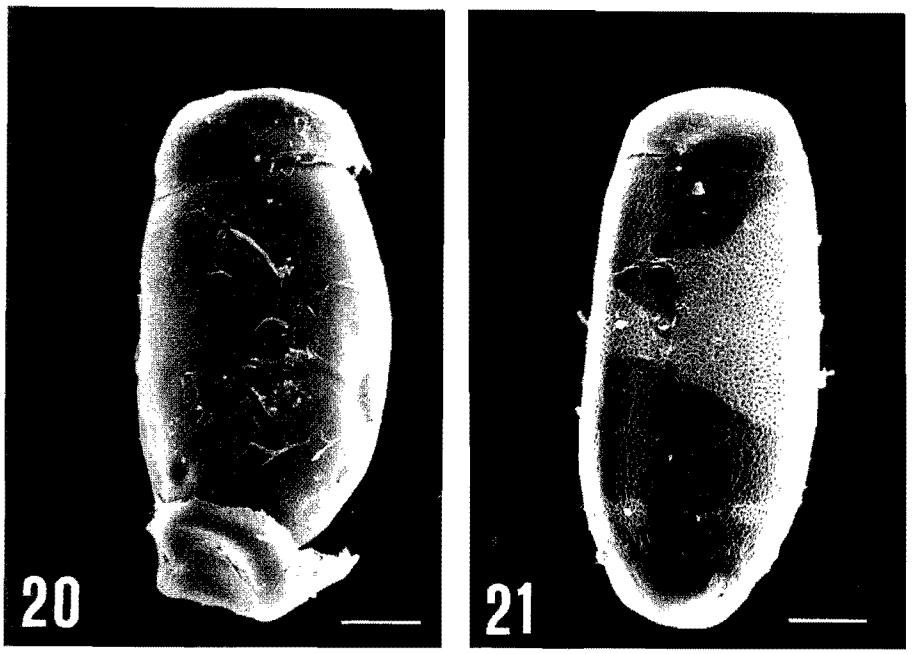








Figs. 16–19. Eggs. 16, *C. argillosa* n.sp.; 17, *C. nitida* n.sp.; 18, *C. bella* n.sp.; 19, *C. cornifera* n.sp. [each scale=20 μm].



Figs. 20–21. Eggs. 20, *C. cornigera* n.sp.; 21, *C. montana* n.sp. [each scale=20 μm].

equatorial area; chorionic surface porous or alveolar, no visible micropyles or other structures.

Holotype: female mature nymph, Wuling Farm, Hoping, Taichung Hsien, Taiwan, (1,500 m), 18–V–1986, P.S. Yang & K.J. Huang, in NCHU.

Paratypes (mature nymph): 2♂♂, 8♀♀, same data as for holotype; 1♀, Thwen, Hoping, Taichung Hsien, (1,800 m), 29–V–1991, S.C. Kang & H.C. Chang. 1♂, 6♀♀, in NCHU; 1♂, 3♀♀, in NMNS.

Distribution: Taiwan

Etymology: montana, L., feminine, meaning dwelling or found on mountain.

Note: This new species resembles *Caenis granifera* n.sp., but can be differentiated in nymphs by the following characters: (1) margins of gena convex strongly and with numerous round granules; (2) middle and hind femur with setae on posterior and anterior margins, on dorsum with a few clavate or fine setae, different from those in *C. granifera*; (3) setae of posterior margin of tergite Ⅷ shorter than in *C. granifera*; (4) body size more larger than in *C. granifera*; (5) operculate gills uniform brown, pale on posterior and lateral margins; (6) lateral margins of operculate gills with fine biforked setae; (7) dorsum of operculate gills with coralloid microtrichiae. The chorion of both species has similar porous surface but the diameters of pores of this species are large than in *C. granifera*.

Acknowledgments

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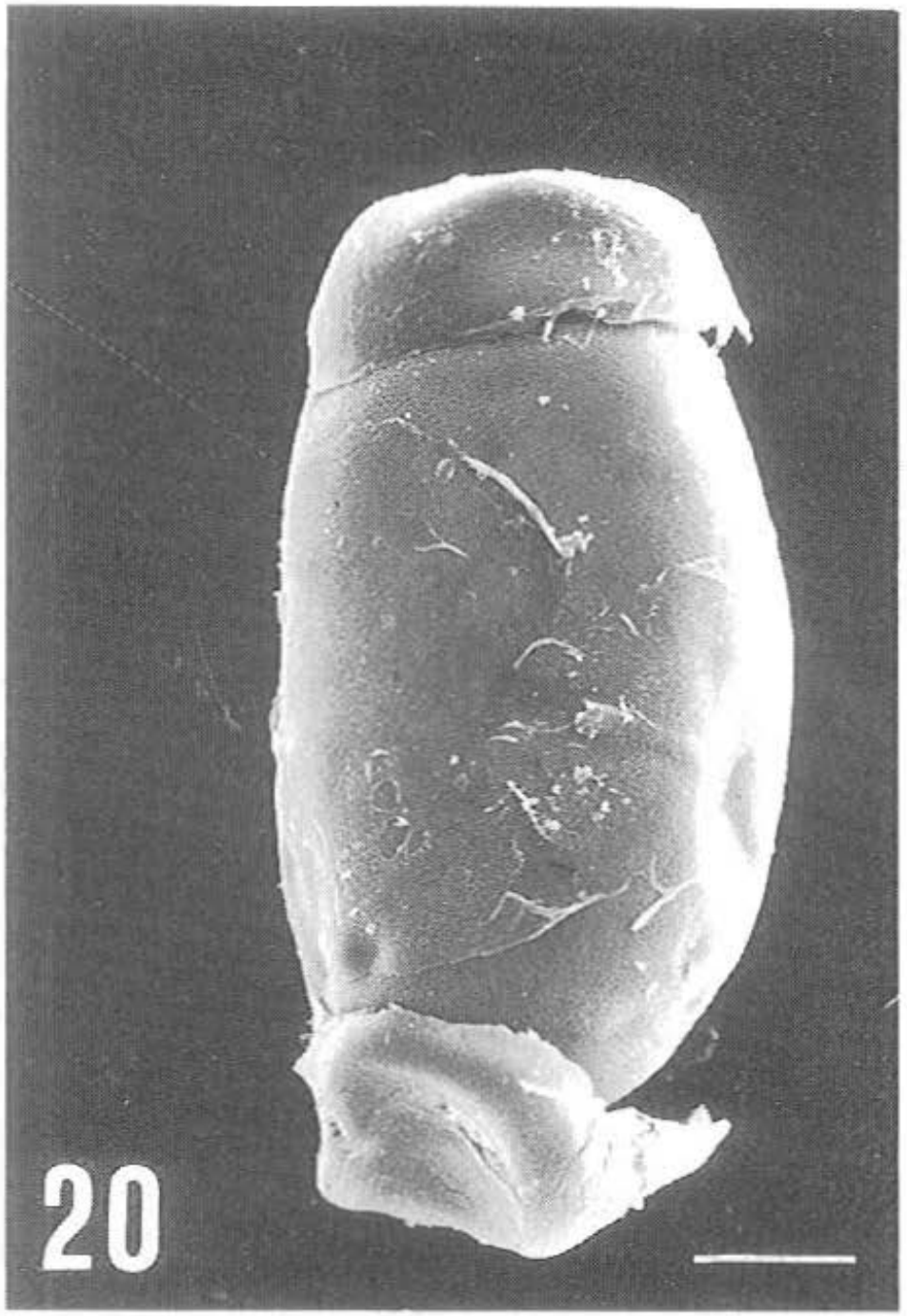
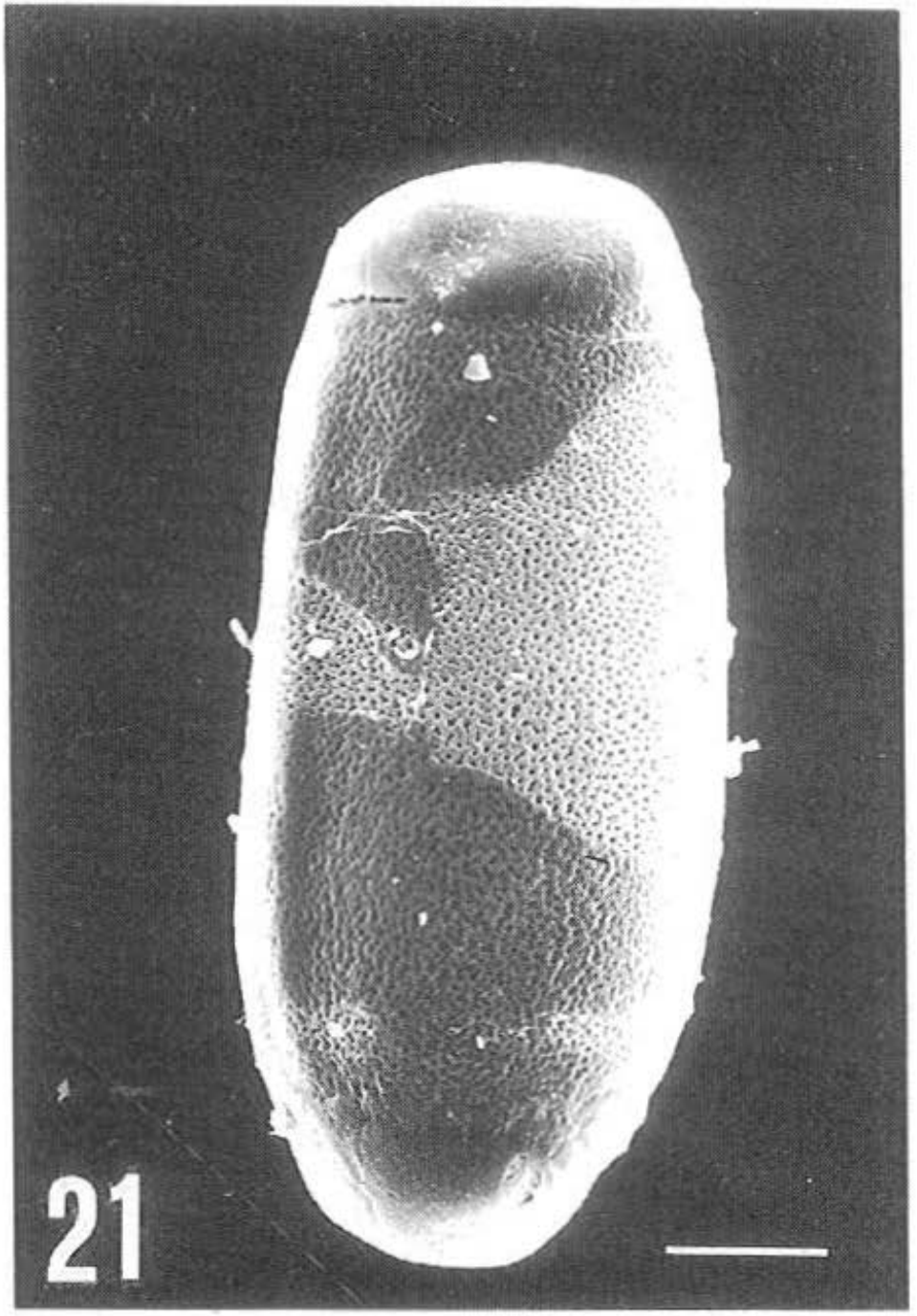
References

Edmunds, G. F., Jr., S. L. Jensen, and





Figs. 20–21. Eggs. 20, *C. cornigera* n.sp.; 21, *C. montana* n.sp. [each scale=20 μm].

L. Berner. 1976. The mayflies of North and Central America. Minneapolis (Univ. Minnesota press) x+ 330 pp.

Ho, K. K.,and S. J. Hsu. 1977. Studies of the aquatic insects of Hsin Tein stream in Taipei area. Ann. Mus. Nat. Hist. Formosa 20: 1–49. (In Chinese with English summary).

Malzacher, P. 1976. Addition to the one-day fly fauna of the Lake Constance area, description of a new species of the genus *Caenis* (Insecta, Ephemeroptera). Beitr. Naturkd. Forsch. Sudwestdtschl. 35: 129–136.

Malzacher, P. 1982. The structure of European Caenidae eggs (Insecta, Ephemeroptera). Stuttgarter Beitr. Naturk. (A) 356: 1–15.

Malzacher, P. The European species of the genus *Caenis* Stephens (Insecta: Ephemeroptera). Stuttgarter Beitr. Naturk. (A) 373: 1–48.

Thomas, A. G. B., and M. Sartori. 1989. Mayflies (Insceta, Ephemeroptera) of Saudi Arabia. Fauna of Saudi Arabia 10: 87–94.

Uéno, M. 1928. Some Japanese mayfly nymphs. Mem. Coll. Sci. Kyoto Univ., Ser. B. 4: 19–63.

Ulmer, G. 1939–1940. Eintagsfliegen (Ephemeropteren) von den Sunda-Inseln. Arch. Hydrobiol. (Supp.) 16: 443–692.

Yang, P. S., C. C. Hon, and K. K. Ho. 1980. A preliminary investigation of mayfly naiads in Tan Shui river. Phytopathologist & Entomologist, NTU. 7: 70–77. (In Chinese with English summary).

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