Two new species of Aptychella (Pylaisiadelphaceae, Musci) from Hawaiian Islands and Taiwan

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Abstract. Two new species of the genus Aptychella, A. hawaiica H. Akiyama & Shevock and A. lini H. Akiyama are described based on specimens collected in the Hawaiian Islands and Taiwan, respectively.

秋山弘之・James R. Shevock: ハワイ諸島と台湾からそれぞれ見つかったオオタマコモチゲ属の2新種

Aptychella Herzog (formerly known as Clastobryopsis M. Fleisch. for Asian species) was revised recently and its phylogenetic position is now recognized as a distinct genus in the Pylaisiadelphaceae s. lat. (Akiyama et al. 2015, Akiyama 2017). More than 20 species have been reported since its establishment as a section under Rhaphidostegium (Schimp.) De Not. (Brotherus 1908). Although several new species were described in recent years (Akiyama 2014, 2015, Akiyama et al. 2010), a thorough taxonomical revision of the genus remains to be done.

Members of Aptychella rarely produce sporophytes and often grow on branches and trunks of short shrubs at wind-blowing mountain ridges and in shallow ravines at mountain slopes, and thus it seems that they reproduce and widen their distribution mainly by filamentous gemmata abundantly produced in leaf axils at upper portion of ascending secondary stems. Such gemmiferous stems form distinctive caudate tips and become much longer than the other short vegetative ones in length and shape. We propose to name the former as gemmiferous caudate stems, and the latter as aggregate short stems. Filamentous gemmata are formed in bundles at the caudate portion and the gemmiferous portions become more or less widened and show a blackish-green coloration in the field. These gemmata are composed of more or less thick-walled rectangular cells at maturity, and are totally smooth.

In most species of Aptychella, leaves of gemmiferous caudate stems and aggregate short ones are usually different in size and length. Alar regions of a leaf
are well differentiated, especially for the former, with pitted, quadrate to rectangular cells arranged in a scalariform manner; each cell differ in size and color, especially those at outer-most margins, which are becoming more or less thin-walled and bulging.

The second author collected Aptychella plants during recent field research in Kaua’i Island, Hawaiian Islands. He found the plants around the summit at the highest peak in the island. Until now, only a single species of the genus, A. robusta Broth., has been reported from Hawaiian Islands (Brotherus 1927, Bartram 1933, Hoe 1973, Staples et al. 2004). Comparing with specimens from Maui and Kaua’i Islands deposited in BISH and NY, we found all of them including our new collection belong to the same taxon. In addition, we recognized the Hawaiian plants differ from typical A. robusta known from Southeast and East Asia in morphological features as described below.

The first author visited central Taiwan in 2013 and in the course of field surveys, he collected a tiny Aptychella plant, which had a slender stipe just below the terminal gemmiferous portion (Fig. 3A). Its linear lanceolate leaves also suggest distant relationship to the other species in the genus. To know their identity, we performed phylogenetic analysis using molecular markers as well as examination of morphological features. Based on this analysis, we confirm their distinctive position in the genus and thus we describe each as new to science here.

Morphological analysis
We examined Aptychella specimens from Asia and Hawaiian Islands deposited in BISH, CAS, HSNU, HYO, NICHI, NY, TAIE and TNM. Holotype and isotype specimens of A. heteroclada (M. Fleisch.) M. Fleisch., A. planula (Mitt.) M. Fleisch., A. robusta and A. yuennanensis Broth. deposited in A, FH and H were also examined.

Molecular phylogenetic analysis
DNA extraction, amplification, and sequencing and phylogenetic analyses were the same detailed in Akiyama (2017) except for different primer sets for rbcL (aF/aR and cF/cR; Hasebe et al. 1994) newly adopted in this study.

All the sequence data, except for the following four taxa, are the same those used in Akiyama et al. (2015). Accession numbers and voucher information of these newly obtained sequences are as follows (in order of rps4, trnL-F and rbcL): A. brevinervis (LC389289, LC389293, LC389285; Yunnan, China, Wang et al. 2013, 26, HSNU), Aptychella hawaiica (LC389290, LC389294, LC389286; Kaua’i Island, U.S.A., Shevock et al. 51156, HYO), A. linii (LC389291, LC389295, LC389287; Taichung, Taiwan, H. Akiyama 23170, holotype, HYO), and A. robusta (LC389292, LC389296, LC389288; Mindanao Island, Philippines, Azulo et al. s.n., Sept. 6, 2007, UC).

In-group terminals were selected from the members of the genus Aptychella and a total eight species of the genus Aptychella are included. In addition, Isocladiella surcularis (Dixon) B.C. Tan & Mohamed, Pylasisadelpha tenuirostris (Bruch & Schimp, ex Sull.) W.R. Buck, P. tristo-viridis (Broth.) Afonina, H. Tsubota & Ignatova, Isopterygium propagiferum Toyma, Yakushimabryum subintegrum (P. Tixier) H. Akiyama were included in the analysis because they had been shown as closely related to Aptychella (Akiyama 2017). Climacium dendroides (Hedw.) Web. & Mohr. and Pleuroziopsis rutheriana (Weinn.) Kindb. ex E. Britton were used as outgroup terminals based on the result of Akiyama (2017). A total of 34 samples (7 genera and 15 species) were used in the analysis.

There was no ambiguity in the alignment except for hyper variable sites of trnL-F, which were deleted and not used in the analyses. Gaps in the alignment were treated as missing data. The aligned combined matrix of the three loci comprised 2310 bps: 658 bps for rps4, 307 bps for trnL-F, and 1345 bps for rbcL.

We performed Maximum Likelihood (ML) and Maximum Parsimony (MP) analyses using MEGA 7.0.21 (Kumar et al. 2016) with the option of “use all sites”, and Bayesian (BI) analyses using MrBayes ver. 3.2.2 (Ronquist & Huelsenbeck 2003). We used T92+G option for ML and BI analyses, which were determined as the optimal model according to the
A phylogenetic tree of 34 taxa inferred by rpo4, trnL-F, and rbcl sequences based on Maximum Likelihood analysis. The numerical value set beside each branch shows BSML, BSMP, and PPBI, respectively. *Climacium dendroides* and *Pleuroziopsis rutenica* are used as outgroup taxa. Scale bar for branch lengths shows the number of substitutions per site.

Akaike’s Information Criterion (AIC: Akaike 1973) as implemented in MEGA 7.0.21.

Two most parsimonious trees were detected for MP analysis with 501 steps in tree length (CI = 0.592105 RI = 0.814593). Trees from ML, MP, and BI analyses do not differ in topology with high support values thus we used the tree inferred from the ML analysis to represent the results (Fig. 1). Bootstrap values of ML (BSML) and MP (BSMP) analyses and posterior probabilities of BI analysis (PPBI) are
shown on each node.

As a result, both Hawaiian and Taiwanese plants were resolved as in-group of the genus *Aptychella* and also located in a separate position from other members of the genus (Fig. 1). As already noted (Akiyama et al. 2015), five samples of *A. robusta* formed two sister clades, none of which are related to the present two species.

**Taxonomic treatment**

1. *Aptychella hawaiica*  H. Akiyama & Shevock sp. nov. (Fig. 2 A–Q)

Closely resembled *Aptychella robusta* in the long caudate gemmiferous stems, acuminated leaves with decurrent alar cells of caudate stems, but differing in weakly recurved leaf margins, 1–2 large cells at the alar region of aggregate short stem leaves.

**Type:** USA, Hawaii, Maui Island, NE Haleakala, Hana Forest Reserve, 0.3 miles SE Waianapanapa, 6700 ft., 7 August 1973, D. R. Herbst s.n. (holotype BISH).

Primary stems tightly attached to the substrata, densely branched. A small number of gemmiferous long caudate stems differentiated from short and aggregate vegetative ones. Gemmiferous stems simple or sparsely branched below, 1–2 cm long, becoming caudate at the tips and bearing gemmæ in leaf axils; uppermost part often becoming naked and flagelliform. Aggregate stems short, to 0.6 cm long, irregularly pinnately or bi-pinnately branched; leaves spreading and sometimes seriatally arranged. Gemmæ present in leaf axils at upper parts of ascending stems, filamentous, to 1.0 mm long, pale brown in older herbarium specimens, numerous; cells 30–40×40–65 μm, smooth, rectangular. Rhizoids numerous, redish brown, densely branching, densely papillose, covering primary stems and lower part of ascending stems. Paraphyllia and pseudoparaphyllia absent. Dormant branch buds covered with scaly leaves. Axillary hairs indistinct.

Leaves of gemmiferous caudate stems and short, aggregate stems are well differentiated. Leaves of gemmiferous stems erect spreading below, loosely appressed above, 2–2.5 mm long, lanceolate from ovate base, acute to long acuminate, more or less narrowed at base, narrowed at base, long and narrowly acuminate; apices often contorted; slightly concave, leaf bases long and narrowly (1–4 cells wide) decurrent to the stem; margins serrulate above, narrowly revolute or plane; costa often indistinct, if present short and divided, reaching 1/6–1/7 (rarely to 1/4) of leaf length; alar cells clearly differentiated, often colored deep reddish brown. Uppermost laminal cells rhomboid to linear, slightly sinuate, evenly thick-walled, 5×25–40 μm, smooth; median laminal cells linear, slightly sinuose evenly thick-walled, 5×60–100 μm, smooth; alar cells varying in shape and size but mostly short to long-rectangular, 7–15×25–50 μm, thick-walled and well-pitted; cells of decurrent part much larger, bulging, long rectangular, to 25×100 μm, thin-walled. Leaves of aggregate short stems roughly arranged in spiral 3-rows, spreading in dry and wet conditions, 0.7–1.2 mm long, ovate, more or less concave, variable in apex, i.e., acute or long acuminate; alars narrowly differentiated, colored reddish brown; costa indistinct; margins weakly crenulate above, entire below, plane or narrowly recurved. Laminal cells similar to those of gemmiferous leaves; alar cells short to long rectangular, 7–12×12–25 μm, with 1–2 well-marked, large, long rectangular, and thick-walled cells on stems, 12×40–60 μm in size.

Sexual organs and sporophytes not seen.

**Other specimens examined.** USA, Hawaiian Islands, Kaau‘i: Lihu‘e District, about the summit ridge of Kawaiikini, the highest point of Kaau‘i, 22°03’
23°N, 159°29’46.8"W, 5200 ft., 29 Jan. 2018, boggy grassland with Dubautia at cliff face in Metrosideros-Cheirodendron wet forest, on shrub stems in sun, Shevock et al. 51156 (BISH, CAS, HYO, PTBG [DNA sample]): Waimea-Hanalei Districts, Alaka’i Swamp between Kelekua (near head of Halepa’akai Stream) and Wa`alale’a, mossy ohia forest, 4500–4800 ft., W. J. Hoe 3126.0 & 3127.0 (both BISH); *Maui*: Mt. top in marshy soil, 6000 ft., 1878, D. D. Baldwin s.n. (NY); West Maui mountains, along trail to Pu`u Kukui summit, 3000–5500 ft., 24 August 1971, L. E. Bishop 2029 (BISH); Kipahulu Valley, on wet branches and twigs in ohia forest, vicinity of base camp 3, 6375 ft., 28 August 1967, W. J. Hoe 1802.0 (BISH); locality vague beyond reference to East Maui, 1 August 1977, L. Stemmermann 2404 (BISH); ibid., 3 August 1977, L. Stemmermann 2436 (BISH);

**Habitat.** Forming dense and compact turfs on shrub branches and twigs in montane mossy forests at upper elevations.

**Distribution.** Hawaiian islands (Maui Island and Kaua`i Island).

**Distinguishing features.** (1) Well differentiation of ascending secondary stems into gemmiferous caudate and aggregate short ones (Fig. 2A), (2) weakly or only narrowly recurved margins even for leaves of gemmiferous caudate stems (Figs. 2F–I), (3) well developed alar regions with distinct decurrence to stems in gemmiferous caudate stem leaves (Figs. 2J–K), (4) 1–2 large cells at the base of alar regions of aggregate short stem leaves (Figs. 2D–F).

**Taxonomical note.** Comparing specimens from Kaua`i Island and Maui Island, where Aptychella plants were previously reported, plants of the former island are smaller in size and decurrence of gemmiferous caudate stem leaves are narrower. Other morphological features, however, do not show clear differences, and thus we treat them as a single species.

The present new species resembles Aptychella robusta in its acuminate apices, indistinct costa, and distinct decurrence of gemmiferous caudate stem leaves. However, 1–2 large cells at the base of the alar regions (Fig. 2, D & E) of aggregate short stem leaves is an unique features among the members of the genus (similar single large, thin-walled cell is present in some distantly related group, such as *Ectrothecium* Mitt. of the Hypnaceae).

Reporting *Aptychella robusta* from Hawaiian Islands, Bartram (1933) quoted two specimens; one is *Baldwin s.n.* from Maui Island, and the other is *C. N. Forbes 1650K* from Kaua`i Island. The former (*Baldwin s.n.*, Planta Hawaiienne no. 266; see above for more information) is the same one that Brotherus (1927) listed when he first reported *A. robusta* from Hawaiian Islands. We examined a duplicate deposited in NY, and confirmed its identity as belonging to *A. hawaiiica*. Figure 169 in Bartram (1933) shows good characteristic of leaf shape of aggregate short stems of *A. hawaiiica*.

The other specimen, (*C. N. Forbes 1650K*, Kaua`i, Waimea Drainage Basin, West side, 3 July–18 August; BISH) is a problem. Plants in the packet are not *Aptychella*, because alar cells are evenly thick-walled and scarcely bulging, and they are the same in size and arranged in a scalariform manner. In addition, leaves not decurrent to stems. These features well agree to those found in the genus *Gammiella* Broth. *s. lat.* (sense Tan & Jia 1999). Filamentous gemmae found in leaf axes are thin-walled and smooth and thus differs from those usually found in *Gammiella*; cells are short rectangular and more or less mamillose, rarely smooth in the genus. Since monophyletic feature of the genus *Gammiella* is not widely supported (for example, Akiyama 2017), we need further study to determine the identity of this specimen.

One specimen deposited in BISH identified as *A pytchella robusta* (*L. E. Bishop 2042*, West Maui Mountains; summit region of Pu`u Kukui, 5700 ft., 25 Aug. 1971) had small leaves (up to 0.7 mm in length) and scarcely differentiated alars with a few quadrate.

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thin-walled cells, which suggest a close affinity to *Gammiea ceylonensis* B.C. Tan & W.R. Buck

2. **Aptchella linii** H. Akiyama, *sp. nov.* (Fig. 3A-Q)

   Closely resembled *Aptchella oblongifolia* in small plant size and linear lanceolate leaves, but differing in ascending gemmiferous stems reaching 7 mm in height, widely spreading leaves with indistinct costa.

   **Type:** Taiwan, Miaoli Co., Tai’an township, Shei-pa National Park, Syuejin Recreation Area, Shimashian Forest Road, 24°25’N, 121°00’E 1870–1950 m, on tree trunk (*Pinus*) along road in evergreen forest, 8 October 2013, H. Akiyama 23170 (holotype HYO, isotype TAIE).

   Plants yellowish green, brown below, slightly shiny, forming a small patch. Primary stems shortly prostrate, densely branched and bearing ascending secondary short stems. Gemmiferous stems to 7 mm long, with distinct stipes below the short gemmiferous portion at tips; leaves widely spreading but tightly appressed at stipe portion. Ascending stems without gemmae to 4 mm long. Gemmae present in leaf axils at upper parts of ascending stems, filamentous, 0.3–0.7 mm long, pale brown in older herbarium specimen, numerous; cells smooth, quadrate to rectangular, 12–25×12–40 μm. Rhizoids numerous, reddish brown, densely branching, densely papillose, covering primary stems and lower part of ascending stems. Pseudoparaphyllia and axillary hairs not observed.

   Leaves of long stems with gemmae and short stems without gemmae not differentiated in shape and length: slightly shiny, straight, narrowly lanceolate, 1.2–2.1 mm long, straight, more or less plicate; margins narrowly recurved to the base, entire to slightly crenulate; costa indistinct; upper lamina cells rhomboid to linear, evenly thick-walled, 40–60 μm long; median lamina cells linear, slightly sinuate, evenly thick-walled, mostly 80–100 μm long; lower lamina cells becoming shorter, rhomboid to rectangular, more or less pitted; alars distinctly differentiated, quadrate to rectangular, more or less bulging, thick-walled, pitted, colored in reddish brown. Leaves of stipe part of gemmiferous stems linear lanceolate, 1–1.2 mm long; margins plane, slightly crenulate; costs indistinct; alars weakly differentiated with a few quadrate, thin-walled cells; upper and medina lamina cells linear, slightly sinuate, 40–60 μm long.

   Sexual organs and sporophytes not seen.

   **Other specimens examined.** None.

   **Habitat.** Forming a small patch on tree trunk along a trail in montane evergreen forest developing on mountain slope.

   **Distribution.** Known only from the holotype collected from Central Taiwan.

   **Distinguishing features.** (1) Plants small compared to other congeneric species, (2) gemmiferous stems short, straight and not caudate (Fig. 3A). (3) leaves straight and narrowly lanceolate, widely spreading in both dry and wet conditions (Figs. 3B–D).

   **Taxonomical note.** This new species is named after Prof., Dr. S.-H. Lin, who has contributed very much to the progress in bryophyte flora of Taiwan as well as mentoring and training of a number of young bryologists.

   Very small plant size is one of the distinguishing features of *Aptchella linii*. We searched in the herbaria of TNM and TAIE, but failed finding other conspecific specimens. Because of the small size, it might have been overlooked in the field.

   Widely spreading straight and linear leaves look very similar to those of small species of *Acroporium* Mitt. (Sematophyllaceae). In addition, short elliptic shape of gemmiferous portion above slender stipes look as if they are setae and capsules of tiny moss species.

   Three species, *Aptchella brevinervis* (M. Fleisch.) M. Fleisch., *A. planula* (Mitt.) M. Fleisch., and *A. robusta* have been reported previously from Taiwan, (Chiang et al. 2001, Jia et al. 2005). Both *A. planula* and *A. robusta* differ from *A. linii* in larger plant size, distinct long caudate gemmiferous stems usually reaching 1–2 cm in length, wide-ovate leaves with decurrent alars. *Aptchella brevinervis* differs in plicate leaves with a well developed single costa, usually reaching 1/2 of leaf length as well as larger plant size and presence of long caudate gemmiferous stems.
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Literature cited


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