

Arcyria monticola from Hokkaido, northern Japan: its habit, detailed morphology, and comparison with *Arcyria imperialis*

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Abstract *Arcyria monticola* was found in Hokkaido, northern Japan. This is the first record of its locality, except for the type locality. The linearly expanding capillitium with many coils characterizing *A. monticola* consists of very elastic longitudinal tubes, short lateral tubes, and many small intricate nets. A longitudinal tube coils around a small intricate net, which forms a core. In contrast, *A. imperialis*, the other known *Arcyria* species with a linearly expanding capillitium, has neither short lateral tubes nor nets. The microscopic character of the *A. imperialis* capillitium is also totally different from that of *A. monticola*.

Keywords Arcyriaceae · Capillitium · Myxomycetes · SEM · Trichiales

Arcyria monticola Y. Yamam. & H. Hagiw. was described as a new species from the Yatsugatake Mts., Nagano Prefecture, Honshu, Japan (Yamamoto and Hagiwara 2005). This species was previously known only from its type locality. *A. monticola* has a unique capillitium that expands linearly with many coils (Yamamoto and Hagiwara 2005).

The first author of the present study found *A. monticola* in cool-temperate mixed forest of the Uryu Experimental Forest of Hokkaido University in northern Hokkaido (44°22' N, 142°15' E) in October 2007 and November 2008. This is the second report of *A. monticola*.

In the genus *Arcyria* Hill ex F. H. Wigg., a linearly expanding capillitium has been observed only in *A. monticola* and *A. imperialis* (Lister) Yu Li & Q. Wang (\equiv *Hemitrichia imperialis* Lister) (Yamamoto and Hagiwara 2005). The latter was originally described as a species of *Hemitrichia* Rostaf. from Tokyo, Japan (Lister 1929). *A. imperialis* is morphologically similar to *A. monticola* in its outline and also its yellow color.

In this study, the specimens from Hokkaido were mainly examined morphologically and where necessary on their habit. Comparisons of the holotypes of both *Arcyria monticola* and *A. imperialis* and a revised description based on the new morphological findings on *A. monticola* were made.

Twenty-three specimens of *Arcyria monticola* and 19 specimens of *A. imperialis* were examined in this study. The holotypes of *A. monticola* and *A. imperialis* were loaned by the Department of Botany, National Science Museum, Tokyo (TNS) and British Museum (National History) (BMNH), respectively. The specimens collected in Hokkaido are kept in Hokkaido University Museum (SAPA), and the Laboratory of Plant Pathology, Graduate School of Agriculture, Hokkaido University. Collection data of all the specimens examined are shown in Table 1.

The specimens were studied with a stereomicroscope and, after mounting in Hoyer's medium, with a light microscope (LM). Birefringence was studied with a polarizing microscope. Spore measurement was made under the oil immersion objective. Scanning electron micrographs (SEM) were taken using a JSM-5310LV in

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Table 1 Specimens examined in this study

Collection no.	Locality	Collecting date	Collector
<i>A. monticola</i>			
NYM-31 (Holotype)	Kita-Yatsugatake, Nagano Pref.	10 Oct 2004	Y. Yamamoto et al.
NYM-30, 32, 33 (Paratype)	Kita-Yatsugatake, Nagano Pref.	10 Oct 2004	Y. Yamamoto et al.
MY-23, 24 (Paratype)	Kita-Yatsugatake, Nagano Pref.	24 Oct 2004	Miki & M. Kobayashi
TNS-M-H 12490, 12491, 12492	Kita-Yatsugatake, Nagano Pref.	14 Nov 2005	M. Kobayashi
TNS-M-H 12516	Kita-Yatsugatake, Nagano Pref.	13 Nov 2005	M. Kobayashi et al.
TNS-M-H 12879	Kita-Yatsugatake, Nagano Pref.	15 Nov 2005	Y. Degawa
TNS-M-H 13083	Kita-Yatsugatake, Nagano Pref.	13 Nov 2005	M. Kobayashi
YK-1815, 1817, 1818, 1819, 1820, 1821, SAPA 4001 (=YK-1816)	Uryu-enshurin, Hokkaido	25 Oct 2007	Y. Yajima
YK-2124, 2125, 2126, 2127	Uryu-enshurin, Hokkaido	4 Nov 2008	Y. Yajima
<i>A. imperialis</i>			
BMNH 4067 (Holotype)	The gardens of the Imperial Palace, Tokyo	23 Jan 1928	– ^a
BMNH 4068 (Paratype)	Tokyo, a culture from spores of the type.	30 Apr 1928	–
TNS-M R 1519, 1520, 1521, 1522	Akasaka-rikyu, Tokyo	23 Jan 1928	–
TNS-M R 1523	Akasaka-rikyu, Tokyo	30 Apr 1928	–
TNS-M-H 518	Nikkou, Tochigi Pref.	22 Sep 1977	M. Izawa
TNS-M-H 1031, 1032, 1034	Natsubo-en, Tochigi Pref.	27 Sep 1978	H. Hagiwara
TNS-M-H 11131	Lake Matsubara, Nagano Pref.	15 Nov 2003	H. Hagiwara
TNS-M-Y 1114	Koze, Yoshidani, Okayama Pref.	14 Nov 1999	K. Fujioka
TNS-M-Y 7123, 7124, 7125	Mt. Kajigamori, Kochi Pref.	15 Sep 1981	Y. Yamamoto
TNS-M-Y 7126	Makugawa-onsen, Fukushima Pref.	28 Oct 1994	M. Hario
TNS-M-Y 7127	Mt. Garyu, Hiroshima Pref.	14 Oct 1998	Y. Harakon
TNS-M-Y 16937	Rashomon, Okayama Pref.	22 Oct 2002	K. Takahashi

^a Collector name not written on the specimen label

Hokkaido University. SEM preparation mainly followed Moreno et al. (2006).

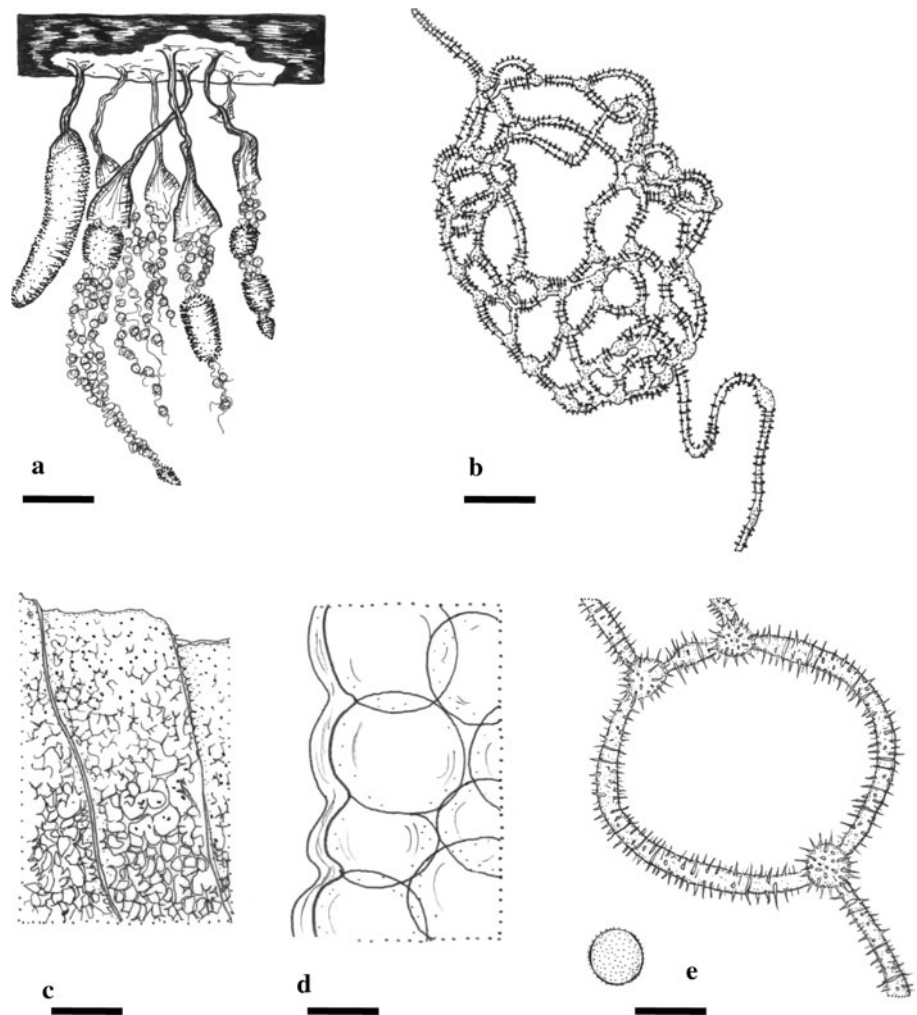
In Hokkaido, *Arcyria monticola* fruited on dead wood of *Abies sachalinensis* (Schmidt) Masters. The wood with bark still attached was very hard to cut so as to remove specimens (Fig. 2c). The sporocarps hung down from the wood, changing their color from brownish yellow to bright yellow as they matured (Fig. 2d). The completely matured sporothecae were very fragile and broke into many small pieces consisting of portions of capillitium and spores (Fig. 1a). Each piece was connected by long linear capillitial threads (Fig. 2b).

The capillitium of *Arcyria monticola* mainly consists of very elastic longitudinal tubes and a few short lateral tubes (Fig. 3f). Five to eight basal longitudinal tubes originate from the stalk apex and inner surface of the calyculus and then branch individually. Each long tube has many small intricate nets at intervals of ~0.2–1 mm. Short lateral tubes arise from these small intricate nets. These lateral tubes are connected to other long ones (Fig. 3f). The tubes often have globose swellings at or near the axils (Fig. 3a). Both the tubes and globose swellings are covered with

rings, half-rings, spines, and cogs when viewed by LM (Fig. 1b, e). These ornamentations are seen to consist of thin pointed processes when examined by SEM (Fig. 3a). A long tube coils around a small intricate net, which forms a core, and some tubes coil around each other. Such a coiled capillitial tube looks macroscopically like a discrete unit when the sporotheca is expanded (Figs. 1a, 2b). The inner surface of the calyculus is mainly covered with a fine reticulum visible with LM and SEM (Figs. 1c, 3b, c). This reticulate ornamentation is observed on the basal part of the calyculus, then gradually becomes incompletely reticulate to spinulose on the marginal part of the calyculus. The outer surface of the calyculus is smooth, delicately membranous (Fig. 3d). This thin membrane continues to the stalk and hypothallus. The stalk is filled with spore-like cells (Figs. 1d, 3e, g). The spores are distinctly verruculose by LM, measuring 10–11 µm in diameter (Fig. 1e). The wartlets with some larger warts are rather randomly arranged when viewed by SEM (Fig. 3h).

In comparison with the holotype, the height and diameter of stalk, capillitium, and spores of the specimens from Hokkaido are slightly greater than those of the holotype

Fig. 1 *Arcyria monticola* (YK-1817). **a** Sporocarps. **b** Small intricate net of capillitium. **c** Inner surface of portion of peridium extending from margin to bottom of calyculus. **d** Spore-like cells in the stalk. **e** Part of capillitium and a spore. Bars **a** 1 mm; **b** 50 μ m; **c** 25 μ m; **d** 20 μ m; **e** 10 μ m



(Table 2). The heights and diameters of sporocarps and sporothecae are not measurable, because all the sporothecae of the holotype have already expanded (Fig. 2a). Other morphological characters, i.e., color, structure, and surface ornamentation of sporophores, stalk, hypothallus, calyculus, capillitium, and spores, correspond to those of the holotype specimen.

The morphological characters of *Arcyria monticola* collected from Hokkaido correspond very closely to those of the holotype. In comparison with the original description with line drawings and all examined specimens including the holotype, the ornamentations of spores and the inner surface of the calyculus are slightly different. Although the line drawing of a spore shows a few wartlets only (Yamamoto and Hagiwara 2005), the wartlets of spores can be clearly observed by LM in all the specimens examined, and correspond to the original description “spores . . . minutely verruculose.” According to the original description, the ornamentation of the inner surface of the calyculus is distinctly reticulate. This ornamentation is observed in

all the specimens examined. However, there is another kind of ornamentation. A distinctly reticulate ornamentation is observed on the basal part of the calyculus, and this gradually becomes incompletely reticulate to spinulose near the marginal part. These observations on spores and the inner surface of the calyculus are additional detailed characters of *A. monticola*.

The capillitial structure of *Arcyria monticola* is unique in the species of *Arcyria*. The capillitium consists of very elastic longitudinal tubes with small intricate nets and short lateral tubes. The short lateral tubes, which are not mentioned in the original description, are connected with longitudinal tubes. These capillitial tubes make a large and loose net, and the netted capillitium is one of the important morphological characters in the genus *Arcyria*. This unique capillitial character of *A. monticola* was observed in all the specimens examined in this study.

In the original description, *Arcyria monticola* was collected at about 2000 m alt., in the subalpine zone of Mt. Yatsugatake (Yamamoto and Hagiwara 2005). In

Fig. 2 *Arcyria monticola* (a NYM-31; b YK-1817).
a Holotype specimen.
b Linearly expanding capillitium with many coils. Arrow, small mass consisting of netted capillitium and spores.
c Fructification on dead coniferous wood still retaining bark. Arrow, fructification.
d Growth habit. Bars a 3 cm; b 2 mm; c 5 cm; d 5 mm



Hokkaido, the species was collected in a low altitudinal northern mixed forest, about 300 m alt. The study site lies adjacent to Lake Shumarinai, where the lowest temperature in this region of Japan has been recorded. The average temperatures of October 2007 and November 2008 were 6.1 and -0.4°C , respectively (Japan Meteorological Agency 2009). Up to now, all the specimens of this species were collected on coniferous wood, in October and November; this seems to indicate that the sporulation period of *A. monticola* is in late autumn, and that it prefers cold weather and coniferous wood.

Myxomycetes found exclusively with fresh sporocarps and mostly in humid and cool environments in late autumn are called late-autumn myxomycetes (Schnittler and Novozhilov 1998). The late-autumn myxomycetes prefer strongly decaying wood covered with moss, and live mainly on the surface of the wood. Fructification of *Arcyria monticola* occurs in fresh conditions in a cool environment in late autumn, however, not in a humid one. It is also noteworthy that the substrate of *A. monticola* is slightly decayed, hard, dry wood, with persisting bark. Therefore,

A. monticola is not strictly a late-autumn myxomycete in the sense of Schnittler and Novozhilov.

Arcyria monticola is similar to *A. imperialis* in fructification appearance (Figs. 2d, 4f). The latter species is also forming a linearly expanding capillitium. The spores of *A. imperialis* measure 6.5–7 μm in diameter and are smaller than those of *A. monticola* (Fig. 4e). The ornamentation of spores is inconspicuous by LM and rather densely verruculose with some larger wartlets by SEM. The inner surface of the calyculus of *A. monticola* is mainly reticulate, whereas that of *A. imperialis* is spinulose and arranged in lines (Fig. 4a). The linear capillitium of *A. imperialis* consists of very elastic long tubes covered with spiral ornamentation (Fig. 4b–d). These capillitial threads never have small intricate nets. In addition, *A. imperialis* has no short lateral tubes and does not form a network. It is also remarkable that the capillitial tubes of *A. imperialis* are easy to unwind along the spiral capillitial bands. *A. monticola* is different from *A. imperialis* in its microscopic characters of capillitium, calyculus, and spores, although the species are similar to each other in outline.

Fig. 3 *Arcyria monticola*, scanning electron micrographs (SEMs) (YK-1817). **a** Part of small intricate net. *Arrow*, globose swelling. **b** Inner surface of the basal part of calyculus. **c** Inner surface of the margin of calyculus. **d** Outer surface of calyculus. **e** Surface of stalk. **f** Part of capillitium consisting of long tubes (*LT*), short lateral tubes (*SL*), and small intricate nets (*SN*). **g** Spore-like cells covered with thin membrane. **h** Spore. *Bars* **a, b, c, e** 10 μ m; **d** 20 μ m; **f** 0.2 mm; **g** 5 μ m; **h** 1 μ m

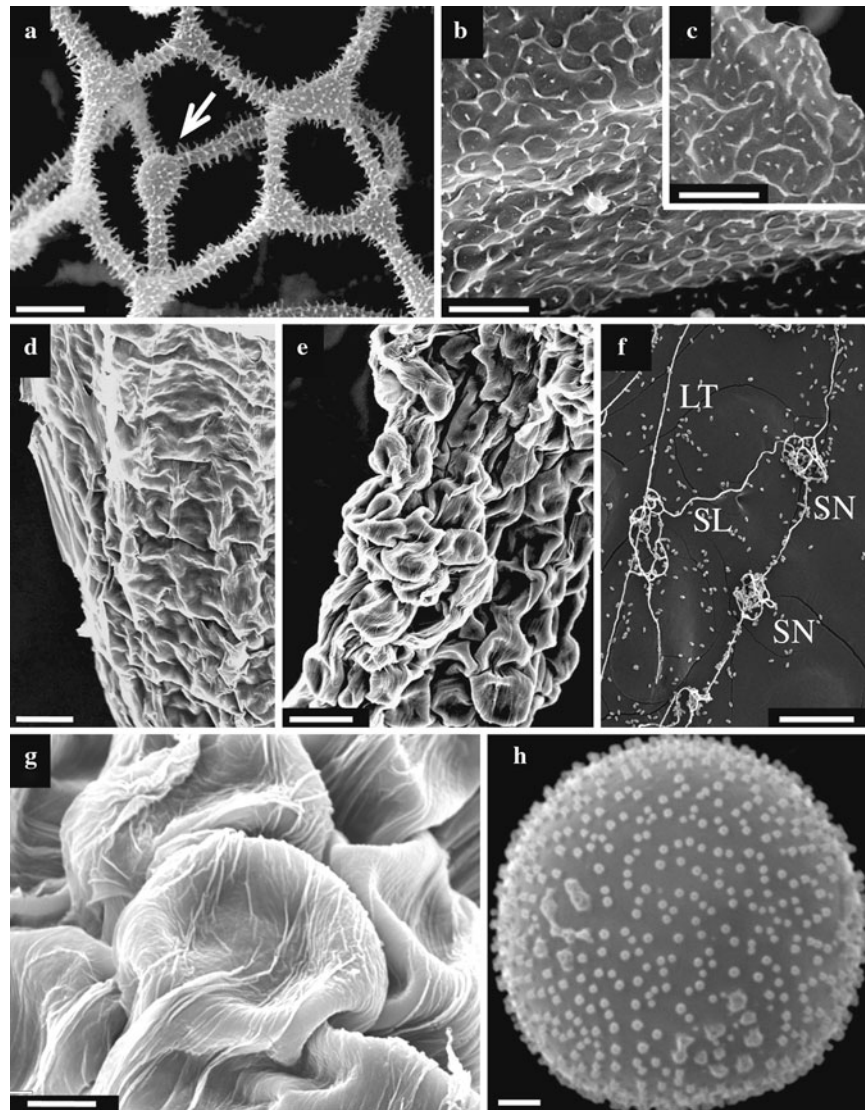


Table 2 Comparison with original description, holotype specimen, and Hokkaido collection

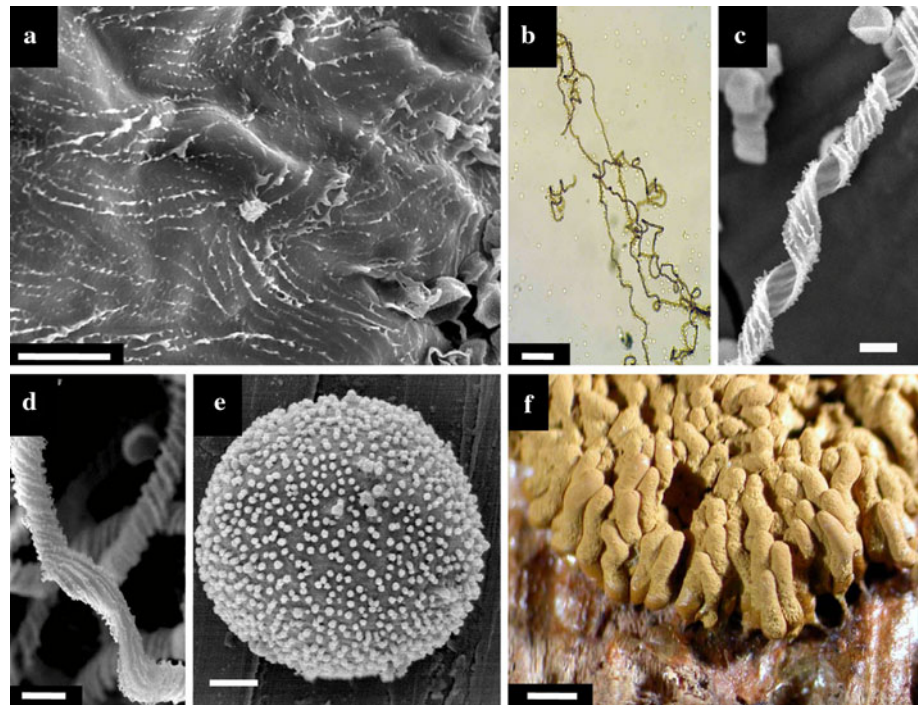
	Original description ^a	Holotype specimen ^b	Hokkaido specimens
Sporophore			
Height	Up to 4.0 mm	ND ^c	Up to 5 mm
Sporotheca			
Height	Up to 2.7 mm	ND ^c	Up to 4 mm
Diameter	0.57 mm	ND ^c	Up to 1 mm
Stalk			
Height	Up to 1.3 mm	Up to 1.3 mm	Up to 2 mm
Diameter	0.15–0.2 mm	0.15–0.2 mm	0.15–0.2 mm
Calyculus			
Diameter	Up to 0.57 mm	Up to 0.6 mm	Up to 0.6 mm
Capillitium			
Diameter	2.5–3 μ m	2.5–3 μ m	2.5–3 μ m
Spore			
Diameter	9.3–10.3 μ m	9.5–10.5 μ m	10–11 μ m

^a Yamamoto and Hagiwara (2005)

^b NYM-31

^c All sporotheca of the holotype specimen had already expanded, and their dimensions were not measurable

Fig. 4 *Arcyria imperialis* (a, c, d, e TNS-M-Y 7125; b TNS-M R 1519; f TNS-M-Y 7125). a Inner surface of calyculus. b Linearly expanding capillitium. c, d Part of unwound capillitium. e Spore. f Unexpanded sporocarps. Bars a 10 μ m; b 20 μ m; c, d 5 μ m; e 1 μ m; f 1 mm



Taxonomic description

Arcyria monticola Y. Yamam. & H. Hagiw., Bull. Natn. Sci. Mus., Tokyo, Ser. B, 31(3): 80. 2005. (Figs. 1–3)

Fructification sporocarpous. Sporocarps gregarious, stalked, up to 5 mm tall. Sporothecae cylindrical, greenish yellow, up to 4 mm tall, 1 mm in diameter when unexpanded. Long capillitium threads and many capillitial coils are exposed when expanded. Stalk often sinuous, pale yellow or ochraceous, longitudinally striate, up to 2 mm long, 0.15–0.2 mm in diameter, filled with spore-like cells, covered with thin membrane. Hypothallus membranous, common to the colony, translucent, yellowish brown or colorless. Calyculus shallow, radially plicate, grayish yellow by reflected light, pale yellow or pale orange by transmitted light, with spines, incompletely reticulate, up to 0.6 mm in diameter. Capillitium filamentous, pale yellow by transmitted light, connected to the stalk apex and inner surface of calyculus, readily released, consisting of very elastic longitudinal tubes with small intricate nets and a few short lateral tubes connected to small intricate nets belonging to other long tubes, often with globose swelling at/near the axils, 3–4 μ m in diameter excluding microsculpture, marked by rings, half-rings, spines, and cogs by LM, covered with thin, pointed processes by SEM, not birefringent. Spores nearly globose, greenish yellow in mass, pale yellow in transmitted light, verruculose with some larger wartlets by LM, rather randomly verruculose with some larger

wartlets by SEM, 10–11 μ m in diameter. Plasmodium not observed.

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