

Spores of Ingoldian fungi in two Austrian rivulets

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Abstract: The species composition of Ingoldian fungi in two rivulets flowing through wooded ravines in Upper Austria were investigated. Both rivulets are located in an area with granite as geological underground. The species composition was investigated by fixed foam which accumulates below small cascades and turbulences, containing often big numbers of spores. 102 different spore forms (including unidentified and unknown forms) belonging to the Ingoldian fungi could be identified and illustrated in line drawings. Especially rich in species was the Kleine Kesselbach, with 98 species having twice as many species as the second rivulet examined, the Leitenbach with 49 species. Species composition is compared with the literature and discussed. This showed that the Kleine Kesselbachtal is at the upper level of species recorded for a single river, which may be due to the ideal structure of the habitat (clear, well aerated water in combination with deciduous ravine forest), but also to the intensive investigations performed over a period of more than one year.

Zusammenfassung: Die Artenzusammensetzung von aquatischen Höheren Pilzen (Ingoldian fungi) in zwei Bächen in bewaldeten Schluchten in Oberösterreich wurde untersucht. Beide Bäche liegen in einem Gebiet mit Urgestein als geologischem Untergrund. Zur Untersuchung wurde fixierter Schaum herangezogen, der sich unter kleinen Wasserfällen und in Strudeln ansammelt und oft Massen an Sporen enthält. 102 verschiedene Sporenformen (inklusive nicht bestimmbarer Arten), die zu den Ingoldian fungi gehören, wurden entdeckt, und die Sporen in Abbildungen illustriert. Als besonders artenreich erwies sich dabei der Kleine Kesselbach, der mit 98 Arten doppelt so viele Arten enthielt wie der Leitenbach mit 49 Arten. Die Artenzusammensetzung wird mit der Literatur verglichen und besonders auffällige Besonderheiten werden diskutiert. Dabei zeigt es sich, daß die Artenzahl des Kleinen Kesselbaches im oberen Bereich dessen liegt, was aus der Literatur für einen Bach bekannt ist. Dieses Resultat ergibt sich aus dem ideal strukturierten Habitat (sauberes, sauerstoffreiches Wasser in Verbindung mit einem laubwerfenden Schluchtwald), vor allem aber auch aus den intensiven Untersuchungen, die sich über mehr als ein Jahr erstreckten.

Ingoldian fungi, also known as "aquatic hyphomycetes" comprise fungi living in fast flowing, well aerated rivers and streams. They live mainly saprophytically on submerged leaves and twigs fallen into the water from the surrounding riverine vegetation. As a special adaptation to their ecological niche they have conspicuous spores (being mainly conidia): They are usually either tetraradiate (i.e. the main axis is branched with the branches growing out in three dimensions) or significantly sigmoid (i.e. distinctly curved sinuously). This spore shape is suggested to play an important role in the colonisation of the substrate. As the Ingoldian fungi live in fast flowing rivers, the spores have difficulties to attach to the substrate. Attachment is facilitated by the tetraradiate spore shape through which they reach the substrate with several arms. In addition, the tips of these arms usually contain a sticky mucilaginous substance (READ & al. 1992) which glues the spores to the substrate. Then, the spores germinate at once, producing germ tubes and immediately thereafter appressoria which results in a rapid and firm adhesion before hyphae grow out to colonise the substratum (READ & al. 1992).

The sigmoid shape of spores has similar advantages as the tetraradiate: Sigmoid spores also touch the substrate at more than one point which favours the adhesion by several simultaneously and rapidly germinating cells (WEBSTER & DAVEY 1984).

In addition to the saprophytic behaviour of most Ingoldian fungi in recent years many species have also been found to live endophytically in roots of riverine trees (mainly alders; see, e.g., FISHER & PETRINI 1989, FISHER & al. 1991), which guarantees the survival in the rivers over the whole year in temperate climates. This is important because leaves which constitute the main substrate are present in high quantity only from late autumn until early winter (October-December) but are rare or absent during the rest of the year. Then, survival is only possible on more durable substrates like submerged wood (SHEARER 1992), endophytically in alder roots or terrestrially along the moist river banks (for detailed information, see BÄRLOCHER 1992). The availability of substrate is highly correlated with the amount of spores present in a river. The number of spores, but also of species reaches its highest level from autumn until early winter when the leaves are shed, and is lower the rest of the year. A detailed summary of the present knowledge of the ecology of the Ingoldian fungi is presented by BÄRLOCHER (1992) and DIX & WEBSTER (1995).

The members of the ecologically defined Ingoldian fungi mainly belong to the hyphomycetes (a group of the mitosporic fungi) which means that their teleomorphs are unknown; however, some belong to *Asco-* or *Basidiomycetes*, and there are also species of *Entomophthorales* (*Zygomycetes*) which produce tetraradiate aquatic spores (WEBSTER & al. 1978, DESCALS & al. 1981); for a summary of the teleomorphs see WEBSTER (1992). This systematic diversity is an impressive indication for the strong selection pressure in fast flowing aquatic environments towards tetraradiate and sigmoid spore shape which evolved parallelly many times in unrelated groups of fungi. As a result, it is clear that the widely used term "aquatic hyphomycetes" is not appropriate as it comprises only hyphomycetes but not the fungi from other systematic groups. Therefore, the term Ingoldian fungi should be preferred as it is not defined systematically but is derived from C. T. INGOLD who is the first investigator of this ecological fungal community and has contributed much towards its exploration.

Also floristically the aquatic community of the Ingoldian fungi has been intensively studied in recent years, and many species lists have been published for several countries, e.g., the USA (PETERSEN 1962, 1963a, b), Sweden (NILSSON 1964), Hungary (GÖNCZÖL 1971, GÖNCZÖL & TÓTH 1974), Spain (DESCALS & al. 1977, 1995a, b), Great Britain (SHEARER & WEBSTER 1985a, b, c), Canada (BÄRLOCHER 1987), France (DESCALS & CHAUVET 1992), India (SRIDHAR & al. 1992) and South Africa (WEBSTER & al. 1994). In Austria only one more comprehensive study is known (REGELSBERGER & al. 1987). Thus, the aim of the present paper is to add further data to the distribution and species composition of Ingoldian fungi in Austria.

Material and methods

There are several methods to investigate species composition of Ingoldian fungi: incubation of submerged leaves in the laboratory until spores are produced; microscopical examination of foam accumulating below small cascades containing often huge masses of spores; observation of spores by millipore filtration of water; and cultivation of spores either isolated from foam or incubated leaves (DIX & WEBSTER 1995). Obviously, the last method is methodically the best one because the cultural characteristics are often essential for reliable identification; however, it is very time-consuming. As most spores of Ingoldian fungi can usually be easily attributed to a certain species, direct examination of spores contained in fixed foam was preferred. However, some species could not be identified reliably by spore shape and size alone; this uncertainty is expressed either by cf. (if more or less referable to a species) or ? (if the attribution to a genus is uncertain).

Sampling. As the spores of Ingoldian fungi trap easily in foam occurring below small cascades, it is easy to examine species composition by examining foam. For this purpose the foam is gathered using a tablespoon, put into small glasses and fixed with 70% ethanol immediately to prevent spore germination. The material was then brought to the laboratory.

Sampling sites. K: Austria, Upper Austria, Innviertel, District Schärding, Kleines Kesselbachtal near the village Wesenufer, small tributary ("Kleiner Kesselbach") of the Danube flowing over granite boulders located in a wooded ravine surrounded by deciduous trees (*Fagus*, *Carpinus*, *Alnus*), 300 m s. m., map grid 7548/2. Sampling was done every 2-5 weeks from Nov. 1991 to Jan. 1993.

L: Austria, Upper Austria, Hausruckviertel, District Grieskirchen, near village Natternbach, Leitenbachtal ("Leithen") E of village Teucht, small rivulet ("Leitenbach") flowing over granite boulders located in a wooded ravine surrounded by deciduous trees (mainly *Fraxinus*, *Acer*, *Carpinus*), 400 m s. m., map grid 7648/2. Three samples were collected (Nov. 1991, Mar. 1992 and Oct. 1992).

Light microscopy. For microscopic analyses a drop of the fixative containing the spores was put on a microscope slide with the aid of a pipette. The liquid was removed by evaporation at room temperature which fixed the spores onto the slide. Then the spores were dyed either with lactophenol-cotton blue or phloxin and, after removal of excessive dye solution, mounted with Kaiser's glycerol gelatine. Microscopic examination was carried out with a Reichert Diavar, drawings were made with a drawing tube. Microscopic slides and the samples containing fixed foam are held in the author's private collection.

Results and discussion

Species recorded (Table 1). Altogether 102 different spore forms were found; of these, 63 could be determined at species level, 20 at genus level and 17 remained unnamed. Species which could not be identified with certainty are marked with cf., uncertain genera by ? Some critical, rare or unknown species are considered in detail below.

In addition to Ingoldian fungi also some tetraradiate spores of terrestrial species were found sporadically in the foam samples; these are listed separately in Table 1 and illustrated (Fig. 9e-h) but not discussed further in the text.

In the Kleine Kesselbach (K) 98 species were encountered, which is double the number found in the Leitenbach with 49 species. This may be partly the result of more thorough investigations in K than L; whereas in K foam was fixed and investigated every 2-5 weeks over a period of 15 months, from L only 3 samples were taken within one year. However, the number of spores trapped in the foam also was much higher in K than in L which is an indication for more favourable conditions in K than in L. This may be due to the fact that the Leitenbach is flowing through intensively manured pastures and fields before entering the ravine, whereas the Kesselbach mainly flows through woods which results in clear oxygen-rich water also indicated by the presence of some algae characteristic for good water quality, e.g., *Hildenbrandia rivularis* (LIEBM.) J. G. AG.

Table 1. Species recorded in the Kesselbach (K) and Leitenbach (L) from spores trapped in foam. The records are listed alphabetically.

Species	K	L	Fig.
Ingoldian fungi:			
Acaulopage dichotoma DRECHSLER	+		10e
Acaulopage spec.	+		10f
Actinospora megalospora INGOLD	+		6a
Alatospora acuminata INGOLD s. l.	+	+	2b
Alatospora acuminata INGOLD s. str.	+	+	2c
Alatospora flagellata (GÖNCZÖL) MARVANOVÁ	+		2g
Alatospora pulchella MARVANOVÁ	+		2d
Anguillospora crassa INGOLD	+	+	6c
Anguillospora longissima (SACCARDO & SYDOW) INGOLD		+	6b
Arbusculina moniliformis (DESCALS) DESCALS & MARVANOVÁ			3a
Articulospora spec.	+		7h
Articulospora tetracladia INGOLD	+	+	7g
Camposporium pellucidum (GROVE) HUGHES	+	+	6f
Campylospora parvula KUZUHA		+	12f
Clavariopsis aquatica DE WILDEMAN	+	+	5g
Clavatospora longibrachiata (INGOLD) SV NILSSON ex MARVANOVÁ & SV NILSSON	+	+	12h
cf. *Colispora elongata* MARVANOVÁ	+		11c
Cryptococcus aquaticus (JONES & SLOOF) RODRIGUES DE MIRANDA & WEJMAN	+		10j, k
Culicidospora aquatica R. H. PETERSEN	+		5e
Culicidospora gravida R. H. PETERSEN	+	+	5d
Dendrospora erecta INGOLD			14, 15
Dendrospora tenella DESCALS & WEBSTER	+		12g, 13a
Dendrospora spec.	+		3c
Dicranidion spec.	+	+	12d
Diplocladiella scalaroides ARNAUD	+	+	10g
Dwayaangam cornuta DESCALS	+	+	5f
Erynia rhizospora (THAXTER) REMAUDIÈRE & HENNEBERT	+		10a
Erynia conica (NOWAKOWSKI) REMAUDIÈRE & HENNEBERT	+	+	10b-d
Flagellospora curvula INGOLD	+	+	11a
Gyoerffyella gmellipara MARVANOVÁ	+		8f
Gyoerffyella rotula (HÖHNEL) MARVANOVÁ	+		8e
?*Gyoerffyella* spec.	+		8g
Helicosporium spec.	+	+	11i
Heliscella stellata (INGOLD & COX) MARVANOVÁ	+	+	12e
Heliscella stellatacula (KIRK ex MARVANOVÁ & SV NILSSON) MARVANOVÁ	+		12i
Heliscus lugdunensis SACCARDO & THÉRRY	+	+	4f
Heliscus spec.	+		4g
Isthmotricladia britannica DESCALS	+		4b
Isthmotricladia spec.	+		4c
Lateriramulosa uniinflata MATSUSHIMA	+		4e
Lemoniera aquatica DE WILDEMAN	+	+	5h

Lemoniera cf. *centrosphaera* MARVANOVÁ	+		5j
Lemoniera terrestris Tubaki	+	+	5i
Lemoniera spec.	+		11j
Margaritispora aquatica INGOLD	+	+	12a
Pleuropedium tricladioides MARVANOVÁ & IQBAL	+		7d
Pseudorobillarda phragmitidis (CUNNELL) MORELET	+		10i
?*Retiarus* spec.	+	+	11f
?*Rhynchosporium* spec.	+		13g
cf. *Sigmoidea aurantiaca* DESCALS	+	+	11l
Speiropsis pedatospora TUBAKI	+		3b
Stenocladiella neglecta (MARVANOVÁ & DESCALS) MARVANOVÁ & DESCALS	+	+	2a
Taeniospora gracilis MARVANOVÁ	+	+	11h
Tetrachaetum elegans INGOLD	+	+	6e
Tetracladium marchalianum DE WILDEMAN	+	+	1a
Tetracladium maxilliforme (ROSTRUP) INGOLD	+	+	1b
Tetracladium palmatum ROLDÁN	+	+	1d
Tetracladium setigerum (GROVE) INGOLD	+	+	1c
?*Tetracladium* spec.	+		1e
Tricladium attenuatum IQBAL	+		8a
Tricladium biappendiculatum (ARNOLD) MARVANOVÁ & DESCALS	+		8b
Tricladium caudatum KUZUHA	+	+	8c
Tricladium curvisporum DESCALS	+		13e
Tricladium gracile INGOLD		+	7f
Tricladium patulum MARVANOVÁ & MARVAN	+		7a
Tricladium splendens INGOLD	+	+	6d
Tricladium spec.1	+		7b
Tricladium spec.2	+		7c
Tricladium spec.3	+		7d
Tricladium spec.4	+		7e
Tricladium spec.5	+		13h
Tridentaria spec.	+		4d
Tripospermum camelopardus INGOLD, DANN & MCDOUGALL	+	+	9b
Tripospermum myrti (LIND) S. HUGHES	+	+	9a
Tripospermum spec.1	+	+	9c
Tripospermum spec.2	+		9d
cf. *Triramulispora gracilis* MATSUSHIMA	+		1f
cf. *Triramulispora obclavata* MATSUSHIMA	+		1g
Tumularia aquatica (INGOLD) DESCALS & MARVANOVÁ	+	+	12b
Varicosporium delicatum IQBAL		+	5a
Varicosporium elodae KEGEL	+	+	5b
Volucrispora aurantiaca HASKINS	+	+	3e
Volucrispora graminea INGOLD, MCDOUGALL & DANN	+	+	3g
Volucrispora spec.1	+	+	3f
Volucrispora spec.2	+	+	3h
Unknown 1	+	+	2e
Unknown 2	+		2f
Unknown 3	+	+	3d
Unknown 4	+		3i
Unknown 5	+		4a
Unknown 6	+	+	5c
Unknown 7	+		10h
Unknown 8	+	+	11b
Unknown 9	+	+	11d

Unknown 10	+		11e
Unknown 11	+		11g
Unknown 12	+		11k
Unknown 13	+		12c
Unknown 14	+		13b
Unknown 15	+		13c
Unknown 16	+		13d
Unknown 17	+		13f
Total species no. of Ingoldian fungi	98	49	
Non-Ingoldian fungi of terrestrial origin:			
Asterosporium spec.	+		9e
Prosthemium stellare RIESS	+		9g
Triposporium spec.	+		9h
Unknown 18	+		9f

Annotations to less common, critical and unknown species.

Alatospora flagellata (Fig. 2g): Spores of this species were found only once in K with several spores and seem to be rather uncommon.

Alatospora pulchella (Fig. 2d): This species is well characterised by the constrictions at the base of the lateral branches; spores were regularly found in K, but never in abundance.

Articulospora spec. (Fig. 7h): These spores which were regularly found in K are somewhat similar to those of *A. tetracladia*, but the branches are much longer.

Campylospora parvula (Fig. 12f): Several spores of this rare species were found only once in L. It is interesting to note that *C. parvula* has also been recorded to grow endophytically in roots of *Alnus glutinosa* (L.) GAERTNER (FISHER & PETRINI 1989).

cf. *Colispora elongata* (Fig. 11c): These spores best assignable to *C. elongata* were commonly found in K. For unequivocal determination, however, the spore ontogeny and cultural characteristics are essential (MARVANOVÁ 1988); therefore no final determination can be given.

Cryptococcus aquaticus (Fig. 10j, k): The propagules illustrated are not spores but the colonies of an aquatic yeast which have developed a more or less tetraradiate shape as an adaptation to the habitat. *C. aquaticus* is rather common in K.

Gyoerffyella gmellipara (Fig. 8f): Spores were regularly found in K and have been isolated from streams several times (MARVANOVÁ 1975).

Gyoerffyella rotula (Fig. 8e): This interesting species was found only once with few spores in K. It is assumed to grow also terrestrially as it was first described by VON HÖHNEL from *Myosotis*-leaves in Tyrol (MARVANOVÁ & al. 1967). However, it has also been frequently found in streams (MARVANOVÁ 1975, INGOLD 1975, REGELSBERGER & al. 1987).

?*Gyoerffyella* spec. (Fig. 8g): Similar spores of this uncommon species were also found by REGELSBERGER & al. (1987).

Dendrospora spec. (Fig. 3c): These spores are quite similar to those of *D. juncicola* IQBAL, which, however, have much more branches (DESCALS & WEBSTER 1980).

Erynia conica (Fig. 10b-d): The spores figured are different tetraradiate aquatic spore types of the same species, *E. conica* (DESCALS & al. 1981). It is interesting to note that *E. conica*, being a member of the *Entomophthorales*, is a parasite of aquatic insects. As it is able to parasitise both the aquatic larvae and the terrestrial adults of its hosts, it is able to form both aerial and aquatic spores, the latter being tetraradiate and therefore adapted to aquatic dispersal (DESCALS & al. 1981). Spores of *E. conica* were commonly found in foam both in K and L.

Erynia rhizospora (Fig. 10a): These common spores are germinating aerial spores of *E. rhizospora* which react to submersion by production of germ tubes, resulting in a tetraradiate shape of the spore (DESCALS & al. 1981). This is a peculiar way how an aerial spore is converted secondarily to a tetraradiate one adapted to dispersal in water.

Isthmotricladia spec. (Fig. 4c): Spores of this type are close to those of *I. britannica* and have also been found by REGELSBERGER & al. (1987).

Heliscus spec. (Fig. 4g): Spores of this type were regularly found by, e.g., REGELSBERGER & al. (1987), WEBSTER & al. (1994), DESCALS & al. (1995b); in the present investigation only one spore was detected in K. Probably, these spores are just aberrant ones of *Heliscus lugdunensis*.

?*Retiarus* spec. (Fig. 11f): Similar spores of this rather common species were also found by DESCALS & al. (1977) and identified as ?*Retiarus* spec. by DESCALS & al. (1995b).

?*Rhynchosporium* spec. (Fig. 13g): Spores of this type were regularly seen in K; similar spores were identified as ?*Rhynchosporium* spec. by DESCALS & al. (1995b).

cf. *Sigmoidea aurantiaca* (Fig. 11l): Spores of this type were often found and are morphologically similar to those of *S. aurantiaca* as illustrated by DESCALS & WEBSTER (1982). However, without observations on spore ontogeny and cultural characteristics no final determination of sigmoid spores can be given.

Speiropsis pedatospora (Fig. 3b): Only one spore has been found in K; it seems to be an infrequent species as it has not been often encountered in streams.

Taeniospora gracilis (Fig. 11h): This species was described by MARVANOVÁ (1977) and is a basidiomycetous anamorph with a *Fibulomyces* teleomorph (*Corticiaceae*).

The spores are very characteristic as they have a clamp-connection at the single median septum. Spores were regularly found both in K and L and resemble var. *enecta* MARVANOVÁ & STALPERS.

?*Tetracladium* spec. (Fig. 1e): These unknown spores are close to those of the genus *Tetracladium*; the mode of branching resembles the upper parts of the spores of some *Tetracladium* species, especially *T palmatum* (Fig. 1d). However, the small filiform basal appendages typical for *Tetracladium* are lacking. Conidia of the same type were also found by BANDONI (1981) in Canada on terrestrial *Scirpus* leaf litter near a stream; in Austria they were found only once in K.

Tricladium spp. (Figs. 7b-e, 13h): Spores belonging to these 5 unidentified species of *Tricladium* were sporadically found in K.

Tridentaria spec. (Fig. 4d): These spores are uncommon and similar spores are figured by INGOLD (1975) as *T. glossopaga* DRECHSLER and by WEBSTER & al. (1994) as *T subuliphora* MATSUSHIMA. However, the present spores are somewhat smaller (about 30-35 µm long) than described for *T. subuliphora* (MATSUSHIMA 1989) and *T. glossopaga* (DRECHSLER 1961). In addition, *T. glossopaga* is assumed to be a terrestrial parasite of rhizopods (DRECHSLER 1961).

cf. *Triramulispora gracilis* (Fig. 1f): These spores were found several times in K. *T gracilis*, originally described by MATSUSHIMA (1975) has also been recorded from South Africa (WEBSTER & al. 1994).

cf. *Triramulispora obclavata* (Fig. 1g): These spores were sometimes found in K. The species was described by MATSUSIMA (1975); meanwhile, it has also been recorded from South Africa (WEBSTER & al. 1994).

Varicosporium delicatum (Fig. 5a): Several spores of this rare but well-defined species were found only once in L.

Volucrispora spec.1 (Fig. 3f): These spores were commonly found in K and L. Similar spores are also illustrated by INGOLD (1975) and DESCALS & CHAUVET (1992).

Volucrispora spec.2 (Fig. 3h): Spores of this shape were rarely found both in K and L; probably they are only aberrant spores of *V graminea* as also figured by ROLDAN (1991).

Unknown 1 (Fig. 2e): These spores are in general morphology similar to those of *Taeniospora descalsii* STALPERS & MARVANOVÁ, a basidiomycetous anamorph described by MARVANOVÁ & STALPERS (1987) but lack the characteristic clamp connection at the branching point. However, as clampless spores of *T. descalsii* are differently shaped (MARVANOVÁ & BÄRLOCHER 1988), the spores cannot be assigned to this species. Another similar species, also a basidiomycetous anamorph, is *Crucella subtilis* MARVANOVÁ & SUBERKROPP which also has a conspicuous swelling at the insertion point of the branches; however, *C. subtilis* has bigger spores with thicker arms and without any septa (MARVANOVÁ & SUBERKROPP 1990).

Unknown 2 (Fig. 2f): These spores might belong to the genus *Curucispora*. Similar spores were found in South Africa (WEBSTER & al. 1994: fig. 3R).

Unknown 3 (Fig. 3d): Similar spores of this rather common species were also figured by REGELSBERGER & al. (1987). Probably they belong to an unknown species of *Tricellula* or *Volucrispora*.

Unknown 5 (Fig. 4a): This spore may belong to the genus *Dendrospora*; however, the branching takes place only at the very base which is unusual for *Dendrospora*. Only one spore of this type has been detected in K. It is interesting to note that similar spores were also found in tropical streams by INGOLD (1956, 1959) in Nigeria and by DIXON (1959) in Ghana; however, concluding from the scale bars, these were much larger than the present spore from K. In addition, the spores from tropical streams have only one central cell giving rise to all branches, whereas in the spore from K branching occurs from several cells (Fig. 4a). Probably, also Unknown 13 belongs to the same species; however, the mode of branching is somewhat different.

Unknown 6 (Fig. 5c): Spores of this type were regularly found both in K and L. At the base a distinct germ pore (detachment scar?) is present. As far as I am aware these spores have not been found elsewhere.

Unknown 10 (Fig. 11g): This uncommon helicoid spore seems to have a wide distribution as it is also figured by, e.g., GÖNCZÖL & TÓTH (1974), REGELSBERGER & al. (1987) and DESCALS & CHAUVET (1992).

Unknown 13 (Fig. 12c): Of this type only one spore was seen once in K; for further notes see Unknown 5.

Unknown 14 (Fig. 13b): Sigmoid spores of this shape and size were commonly found in K; however, there are many species which have such spores. Exact determination is therefore only possible after observation of cultural characteristics and spore ontogeny.

Unknown 15 (Fig. 13c): Only one spore of this type was found in K; it seems that it has not been found elsewhere.

Unknown 16 (Fig. 13d): Spores of this type were sometimes found in K. They somewhat resemble spores of the genus *Tricladium*; as far as I know they have not been encountered elsewhere.

Unknown 17 (Fig. 13f): Spores of this uncommon species were also found by REGELSBERGER & al. (1987). They probably belong to an undescribed species the genus *Tricellula*.

Conclusions. It was apparent that especially the foam samples from K were very rich in species (98 species, including 17 unknown spore forms). The number of species present in K is at the upper level recorded for a single stream; comparably high numbers were, e.g., recorded from the River Teign in Exeter, UK (60; SHEARER & WEBSTER 1985a), the rivulet Ysper in Austria (75; REGELSBERGER & al. 1987) and the Mahai River in Natal, South Africa (62; WEBSTER & al. 1994). The first two rivers mentioned are flowing through mixed deciduous woods and the water chemistry and pH was slightly acidic which is also true for the two sites examined in the present investigations; so it is tempting to suggest that this type of streams may be especially rich in species. However, this cannot be considered to be the rule as outlined by WOOD-EGGENSCHWILER & BÄRLOCHER (1983) and CHAMIER (1992) who have found no fundamental differences in species number but in species composition between acidic and calcareous rivers; and the high number of species recorded in the present investigation is for sure mainly due to intensive observation over a long period of time (over one year) which also results in the detection of rare species. In addition, species composition is varying during the year (SHEARER & WEBSTER 1985b), which raises the necessity to extend the investigations over a longer period of time to get a complete list of species present in one site.

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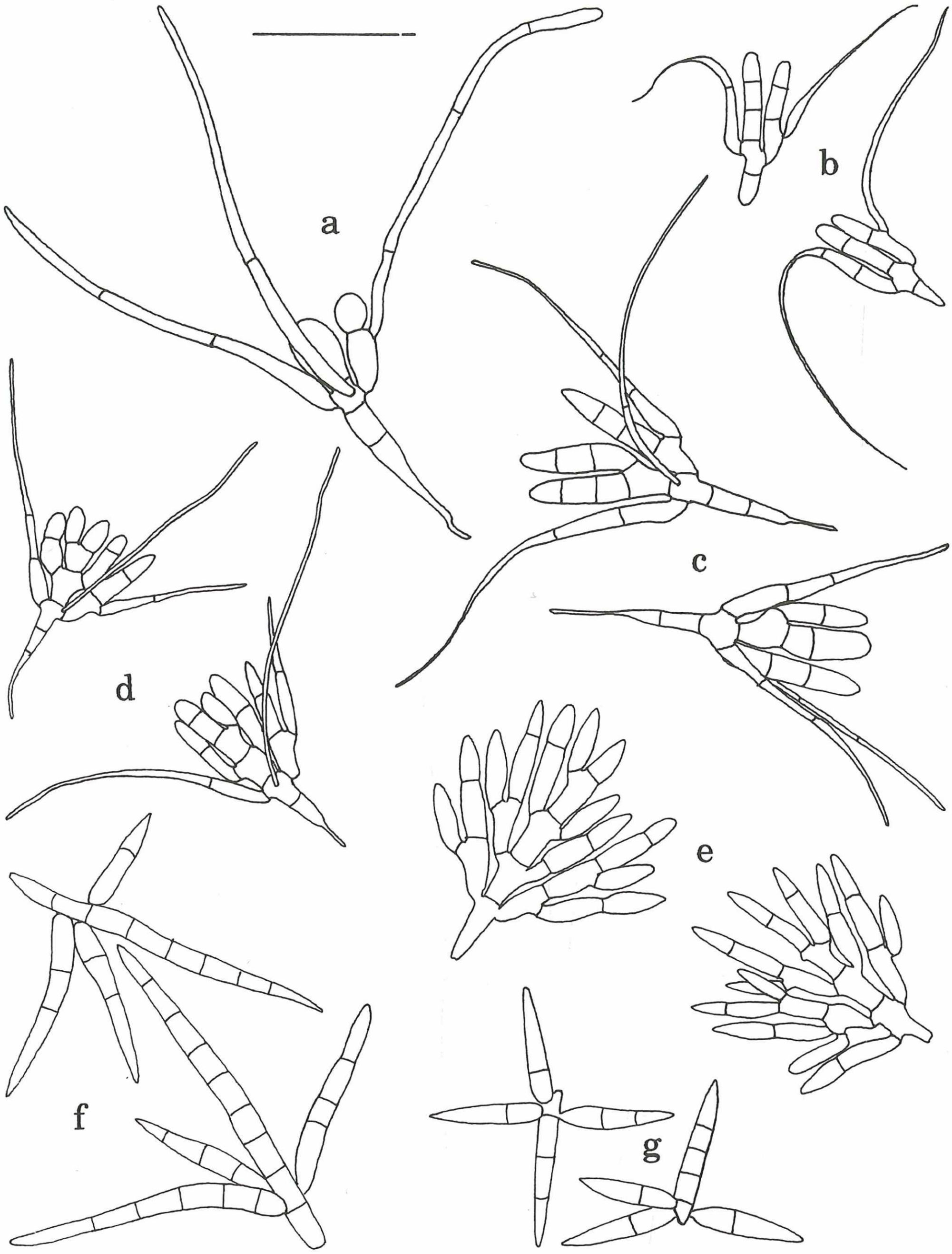

Fig. 1. Spores of Ingoldian fungi. a *Tetracladium marchalianum*; b *Tetracladium maxilliforme*; c *Tetracladium setigerum*; d *Tetracladium palmatum*; e ?*Tetracladium* spec.; f cf. *Triramulispora gracilis*; g cf. *Triramulispora obclavata*. Bar: 20 µm.

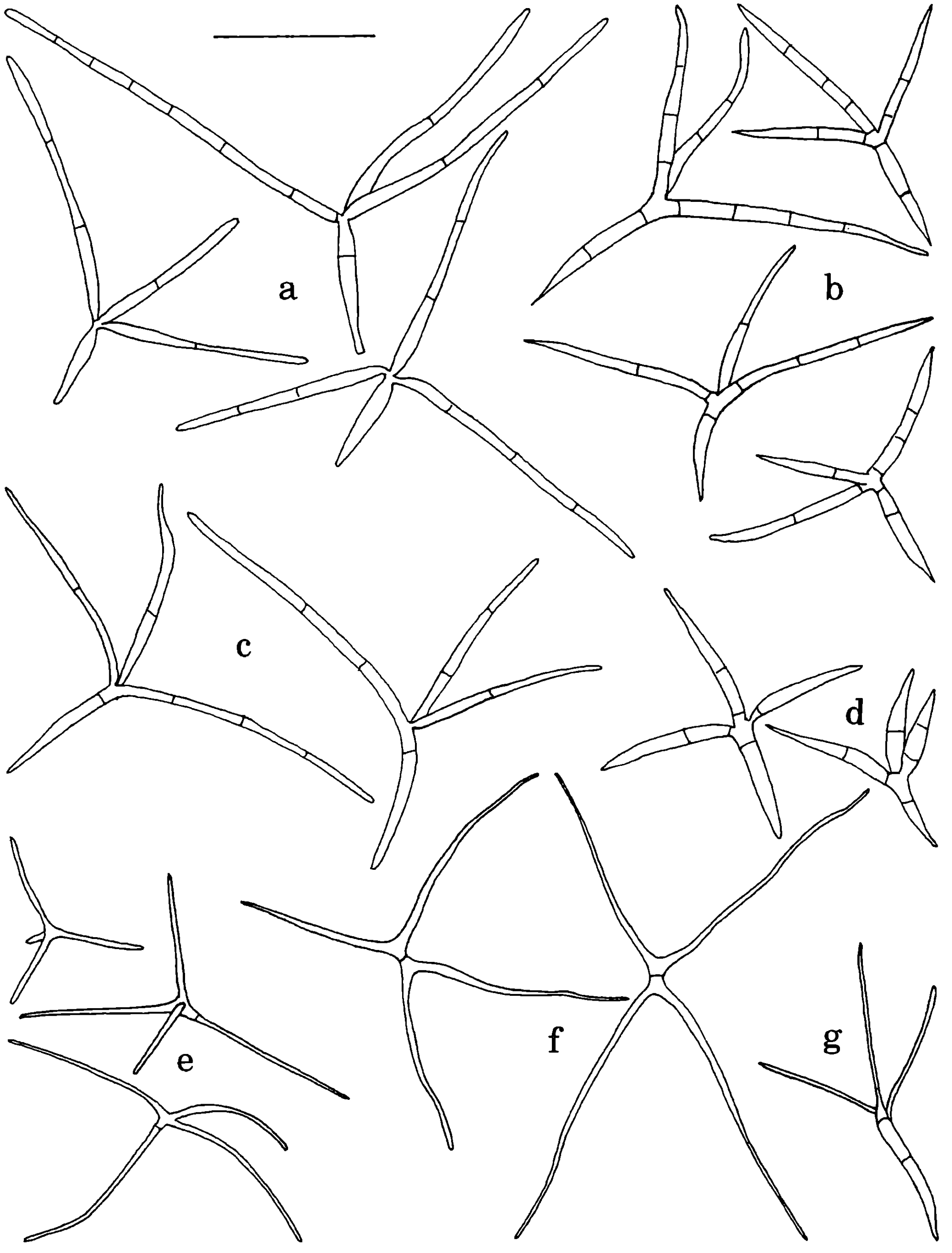

Fig. 2. Spores of Ingoldian fungi. a *Stenocladiella neglecta*; b *Alatospora acuminata* s. l.; c *Alatospora* s. str.; d *Alatospora pulchella*; e unknown 1; f unknown 2, g *Alatospora flagellata*. Bar: 20 µm.

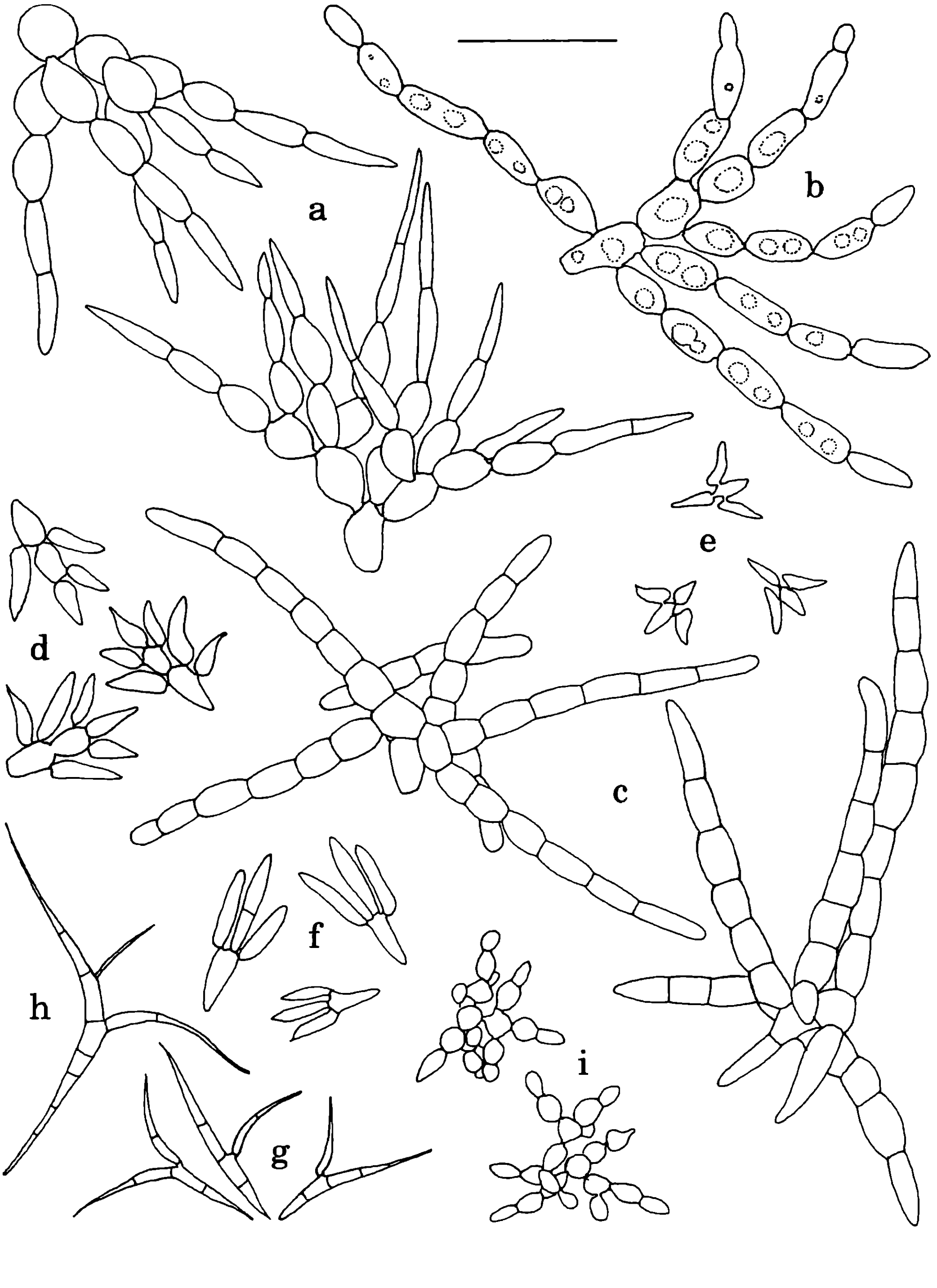

Fig. 3. Spores of Ingoldian fungi. a *Arbusculina moniliformis*; b *Speiropsis pedatospora*; c *Dendrospora* spec., d unknown 3; e *Volucrispora aurantiaca*; f *Volucrispora* spec.1; g *Volucrispora graminea*; h *Volucrispora* spec.2; i unknown 4. Bar: 20 µm.

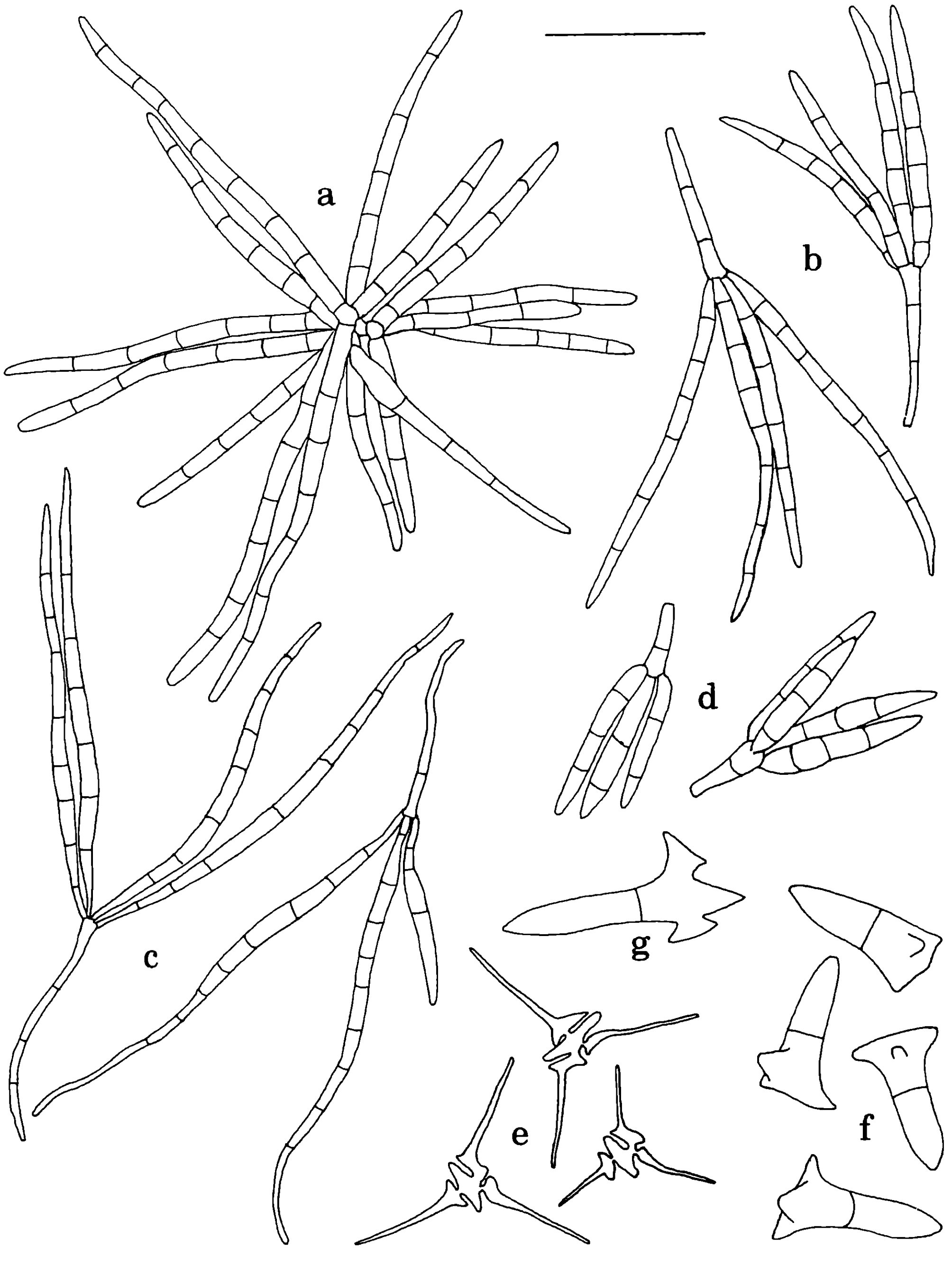

Fig. 4. Spores of Ingoldian fungi. a unknown 5; b *Isthmotricladia britannica*; c *Isthmotricladia* spec., d *Tridentaria* spec.; e *Lateriramulosa uniinflata*; f *Heliscus lugdunensis*; g *Heliscus* spec. Bar: 20 µm.

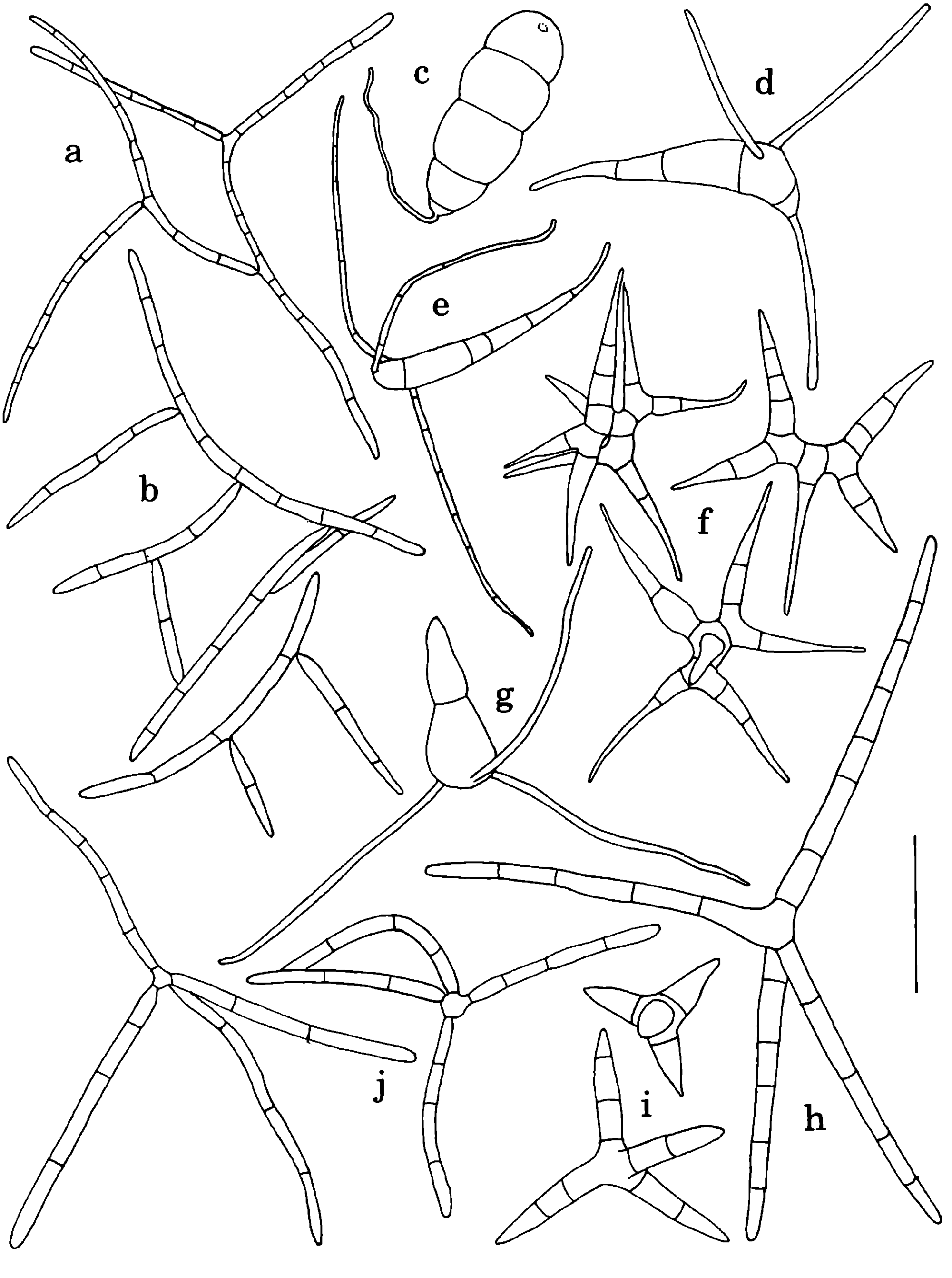

Fig. 5. Spores of Ingoldian fungi. a *Varicosporium delicatum*; b *Varicosporium elodae*; c unknown 6; d *Culicidospora gravida*; e *Culicidospora aquatica*; f *Dwayaangam cornuta*; g *Clavariopsis aquatica*; h *Lemoniera aquatica*; i *Lemoniera terrestris*; j *Lemoniera* cf. *centrosphaera*. Bar: 30 µm.

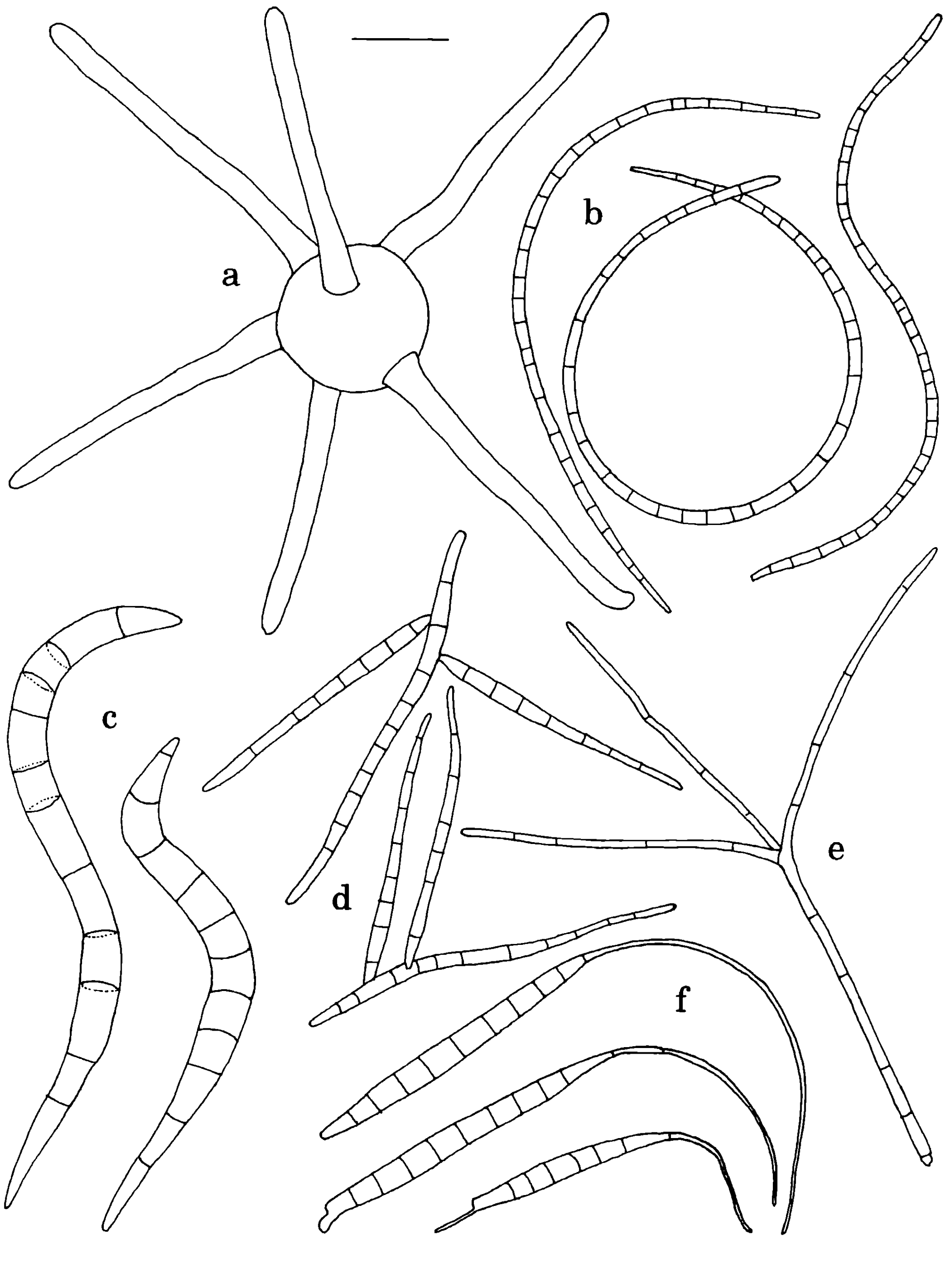

Fig. 6. Spores of Ingoldian fungi. a *Actinospora megalospora*; b *Anguillospora longissima*; c *Anguillospora crassa*; d *Tricladium splendens*; e *Tetrachaetum elegans*; f *Camposporium pellucidum*. Bar: 30 µm.

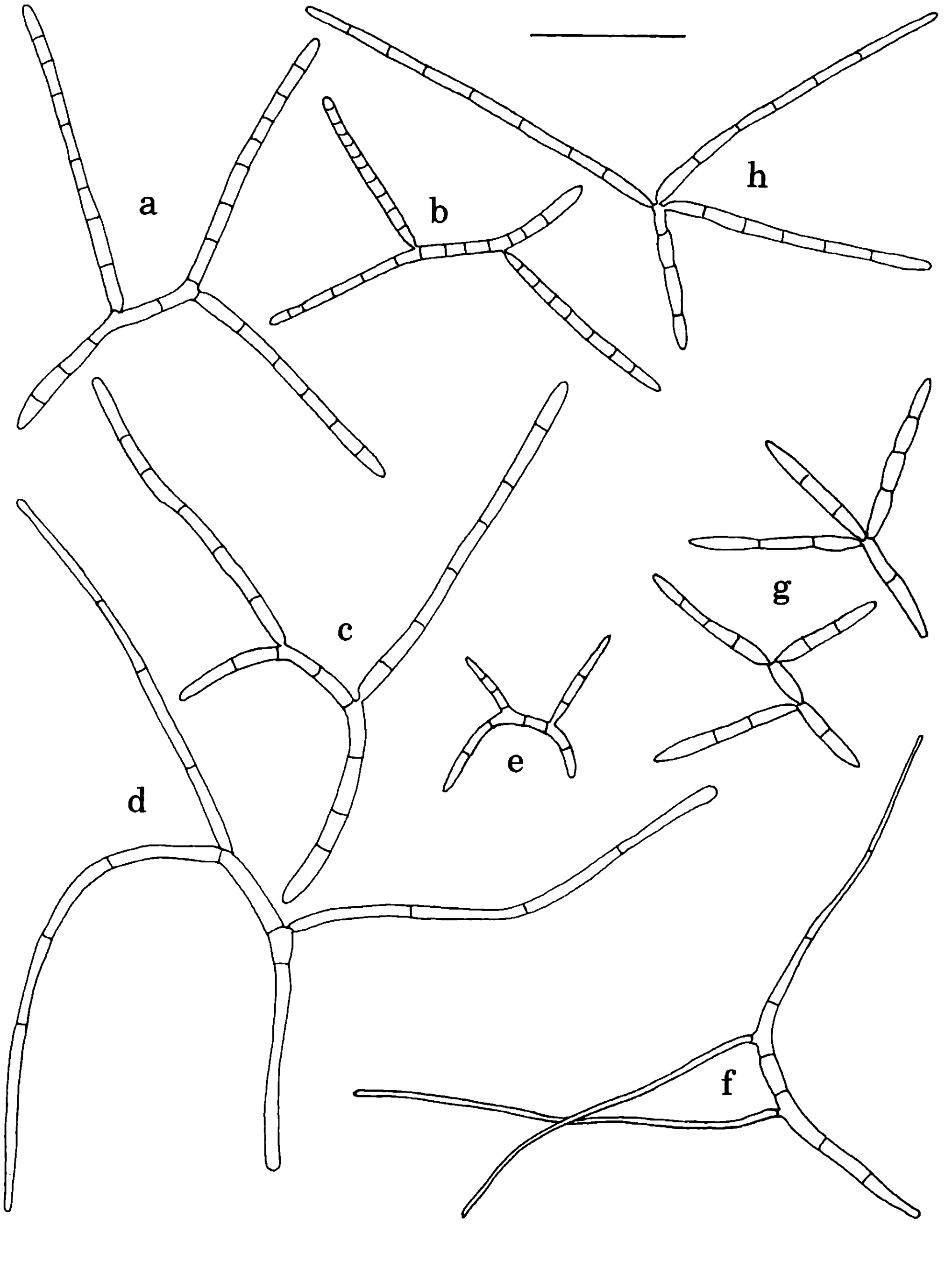

Fig. 7. Spores of Ingoldian fungi. a *Tricladium patulum*; b *Tricladium* spec.1; c *Tricladium* spec.2; d *Tricladium* spec.3; e *Tricladium* spec.4; f *Tricladium gracile*; g *Articulospora tetracladia*; h *Articulospora* spec. Bar: 30 µm.

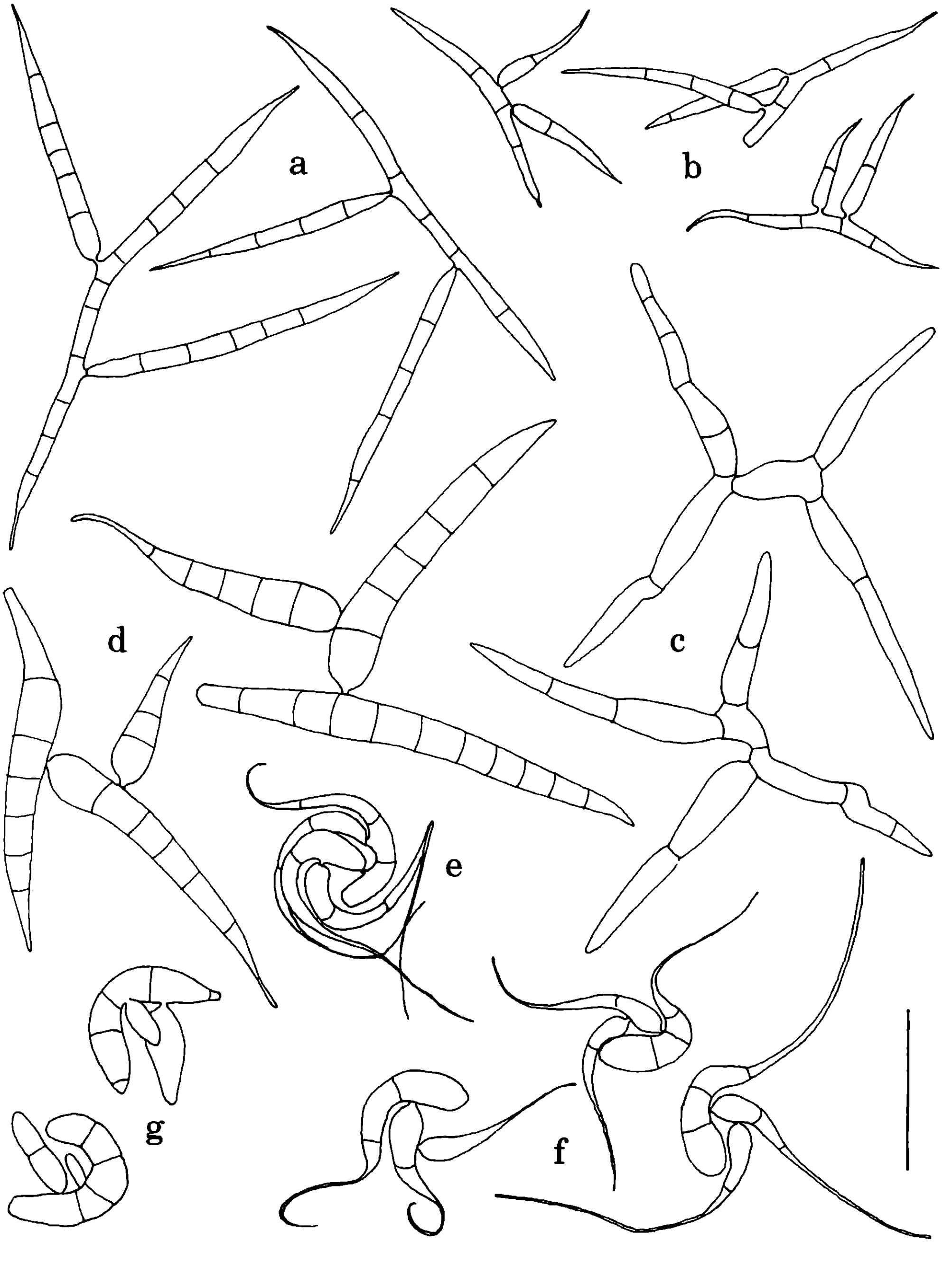

Fig. 8. Spores of Ingoldian fungi. a *Tricladium attenuatum*; b *Tricladium biappendiculatum*; c *Tricladium caudatum*; d *Pleuropedium tricladioides*; e *Gyoerffyella rotula*; f *Gyoerffyella gmellipara*; g ?*Gyoerffyella* spec. Bar: 20 µm.

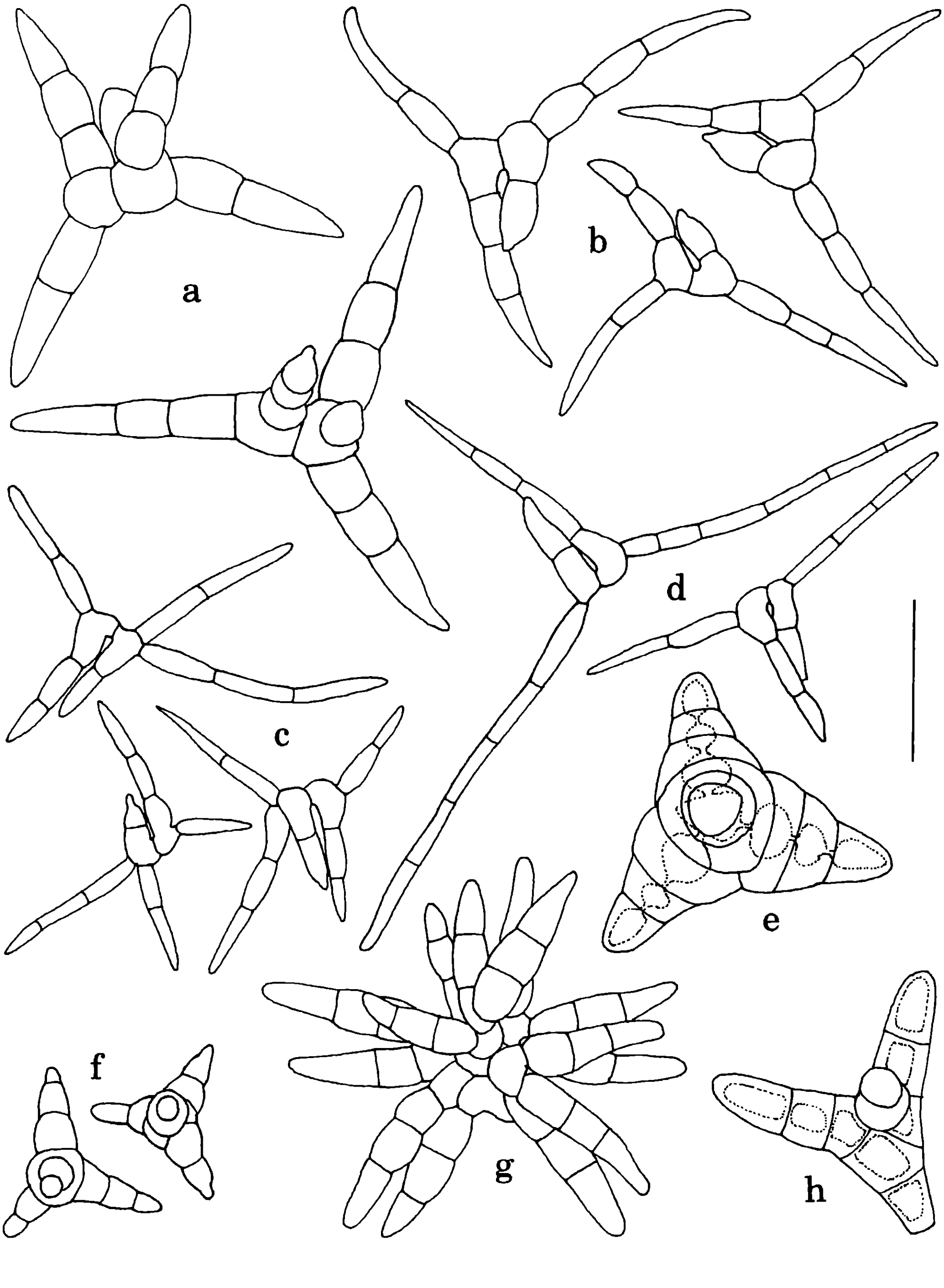

Fig. 9. Spores of Ingoldian and terrestrial fungi. a *Tripospermum myrti*; b *Tripospermum camelopardus*; c *Tripospermum* spec.1; d *Tripospermum* spec.2; e *Asterosporium* spec.; f unknown 18; g *Prosthemium stellare*; h *Triposporium* spec. Bar: 20 µm.

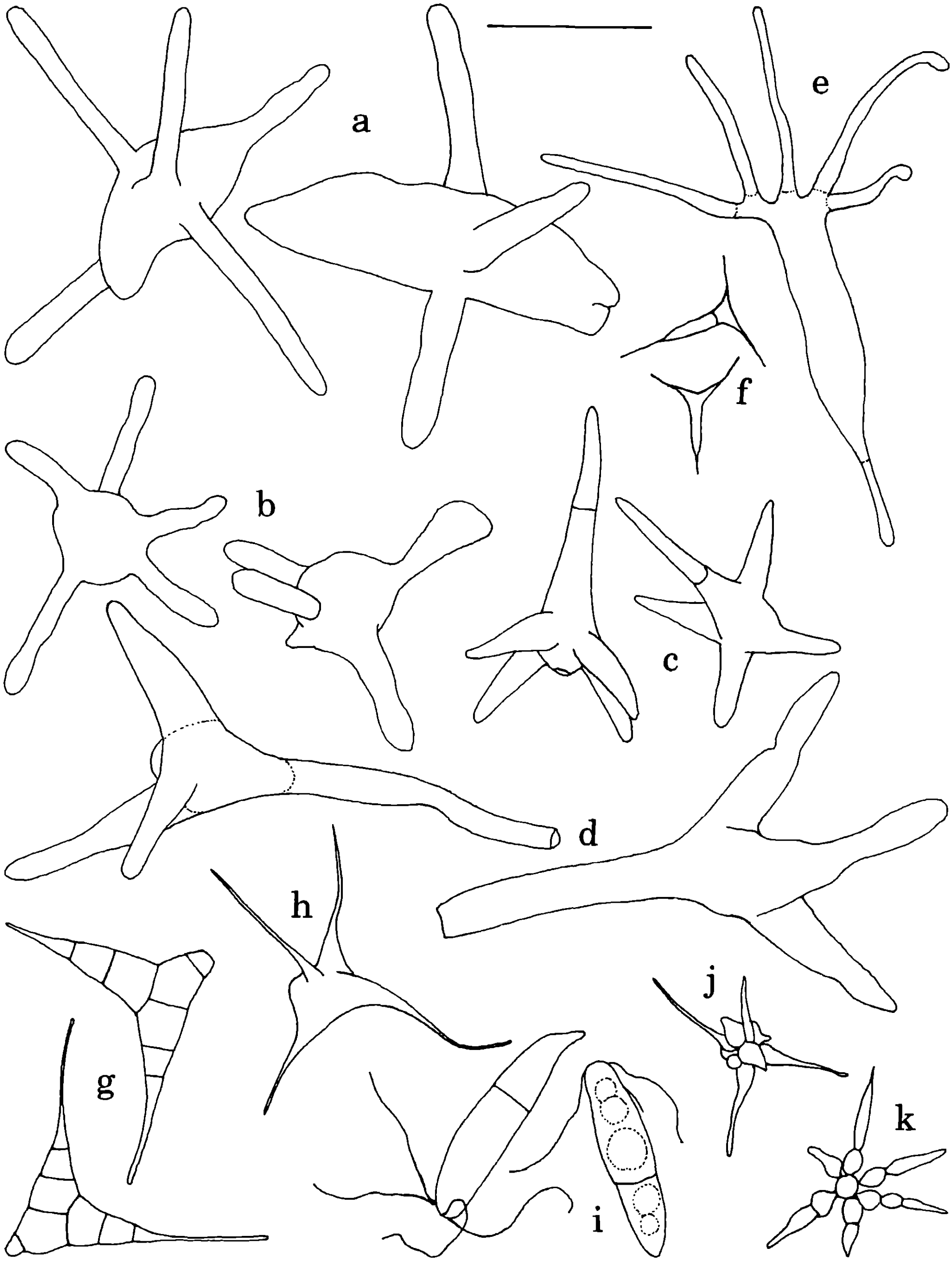

Fig. 10. Spores of Ingoldian fungi. a *Erynia rhizospora*; b-d different spore types of *Erynia conica*; e *Acaulopage dichotoma*; f *Acaulopage* spec.; g *Diplocladiella scalaroides*; h unknown 7; i *Pseudorobillarda phragmitidis*; j, k *Cryptococcus aquaticus*. Bar: 20 µm.

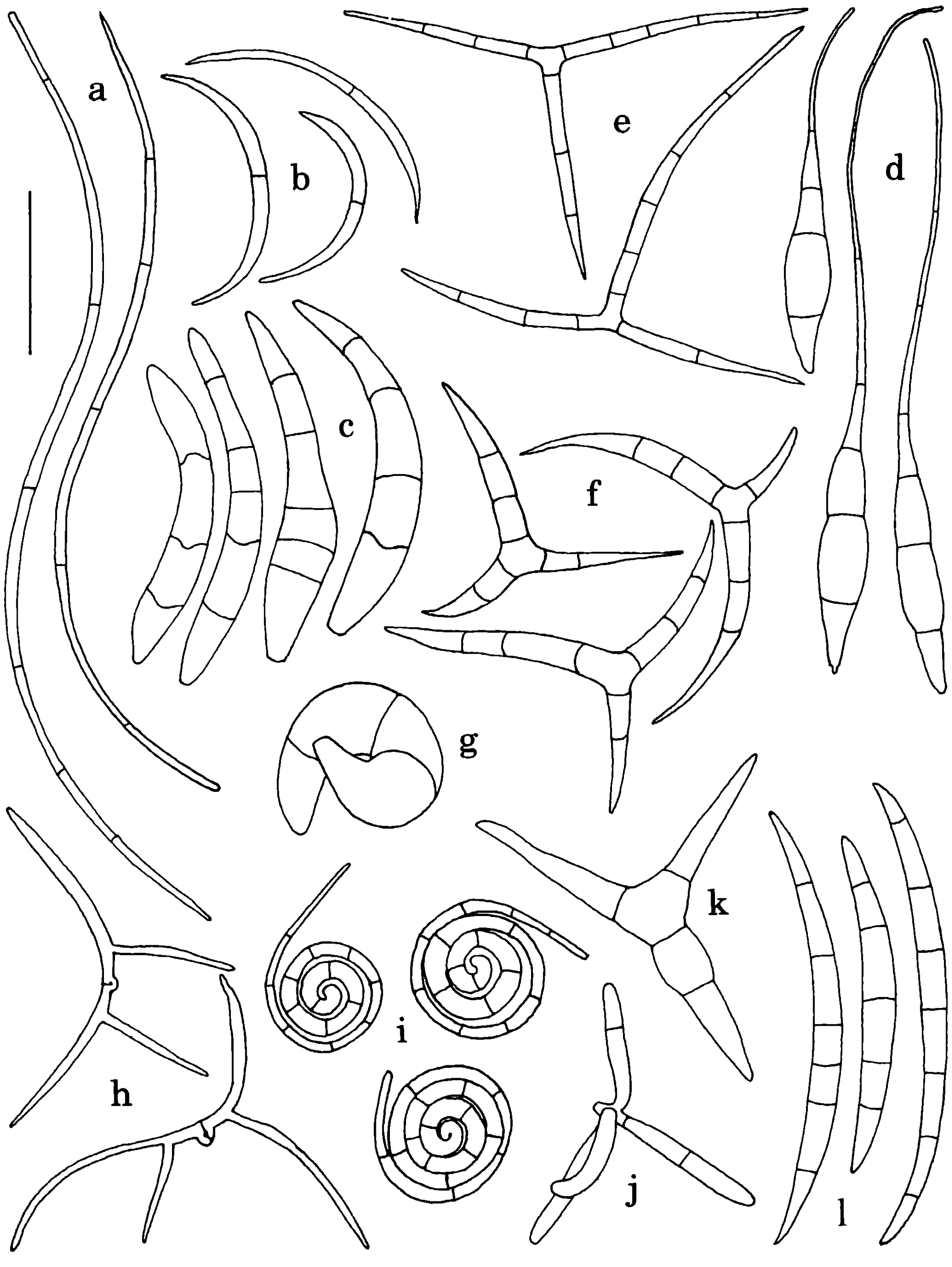

Fig. 11. Spores of Ingoldian fungi. a *Flagellospora curvula*; b unknown 8; c cf. *Colispora elongata*; d unknown 9; e unknown 10; f ?*Retiarius* spec.; g unknown 11; h *Taeniospora gracilis*; i *Helicosporium* spec.; j *Lemoniera* spec.; k unknown 12; l cf. *Sigmoidea aurantiaca*. Bar: 20 µm.

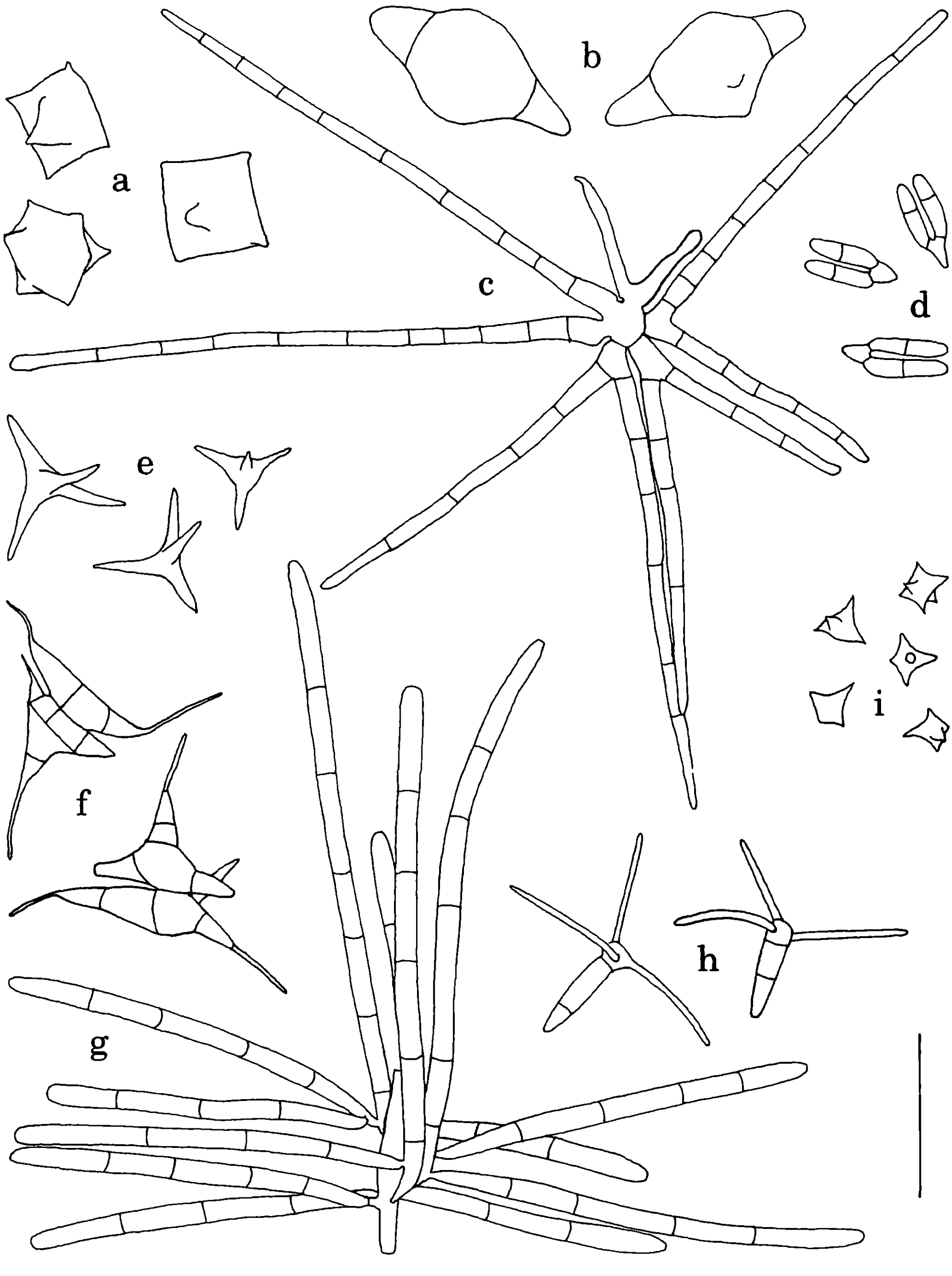

Fig. 12. Spores of Ingoldian fungi. a *Margaritispora aquatica*; b *Tumularia aquatica*; c unknown 13; d *Dicranidion* spec.; e *Heliscella stellata*; f *Campylospora parvula*; g *Dendrospora tenella*; h *Clavatospora longibrachiata*; i *Heliscella stellatacula*. Bar: 20 µm.

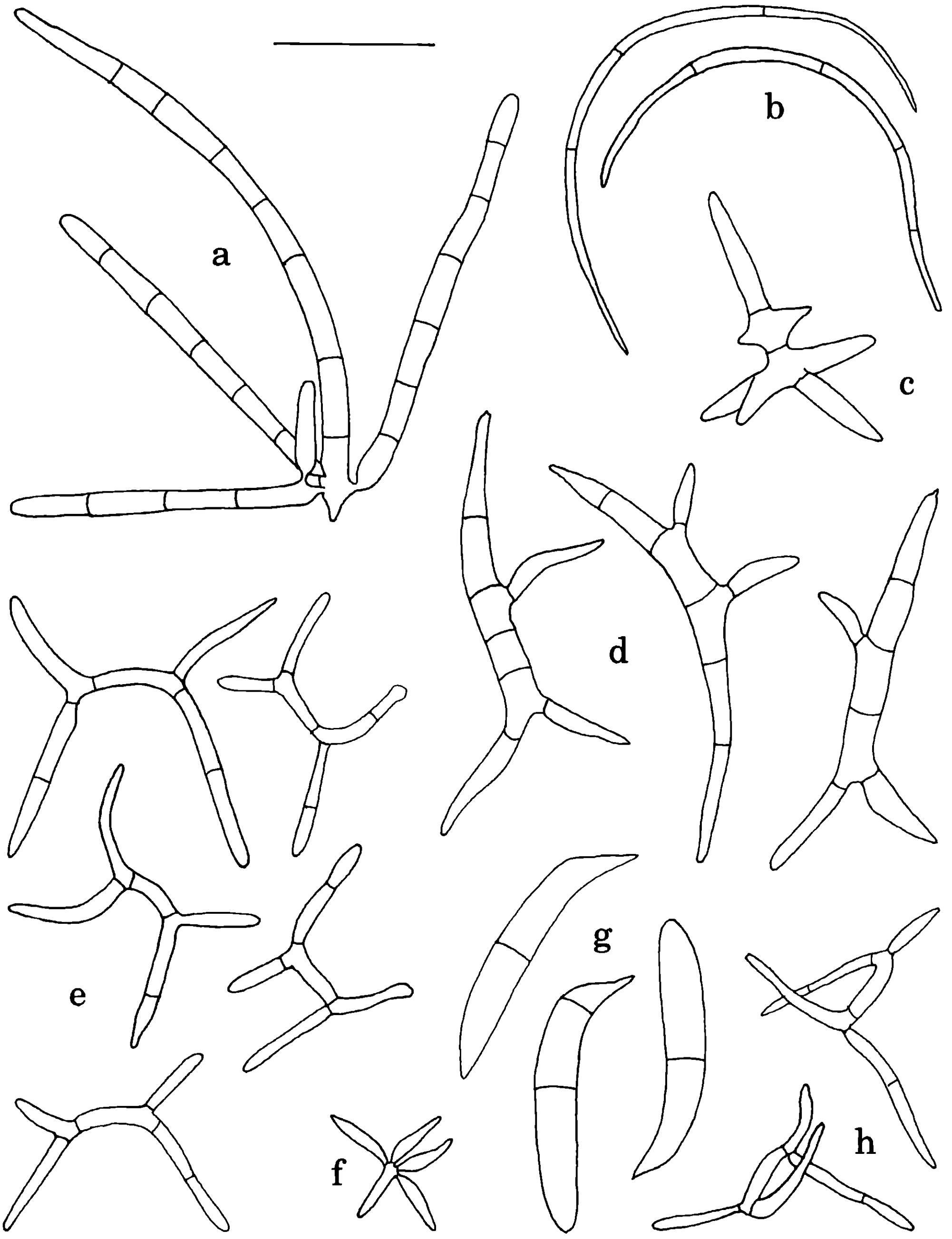

Fig. 13. Spores of Ingoldian fungi. a young spore of *Dendrospora tenella*; b unknown 14; c unknown 15; d unknown 16; e *Tricladium curvisporum*; f unknown 17; g ?*Rhynchosporium* spec., h *Tricladium* spec. 5. Bar: 20 µm.

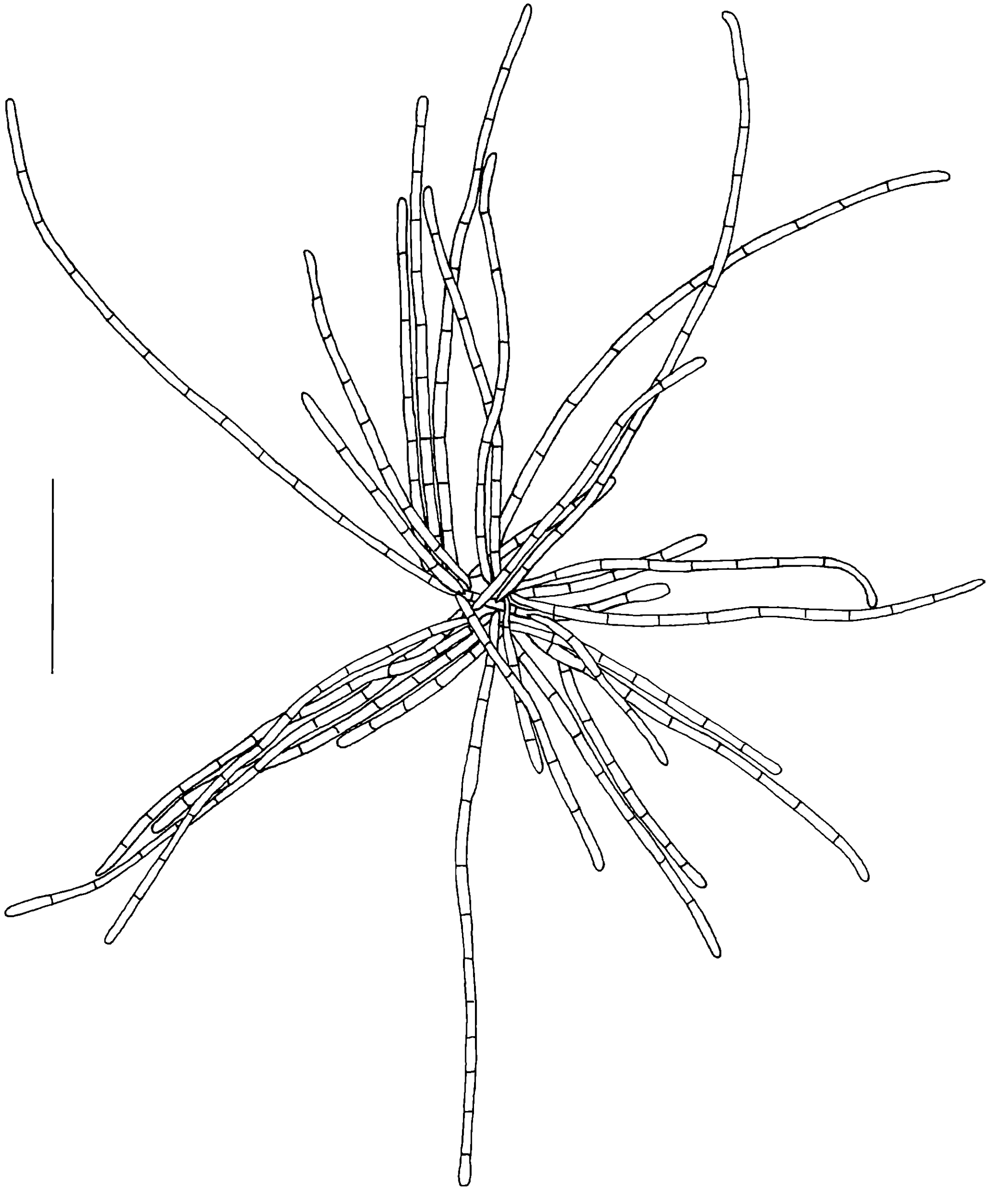

Fig. 14. *Dendrospora erecta*. Bar: 50 µm.

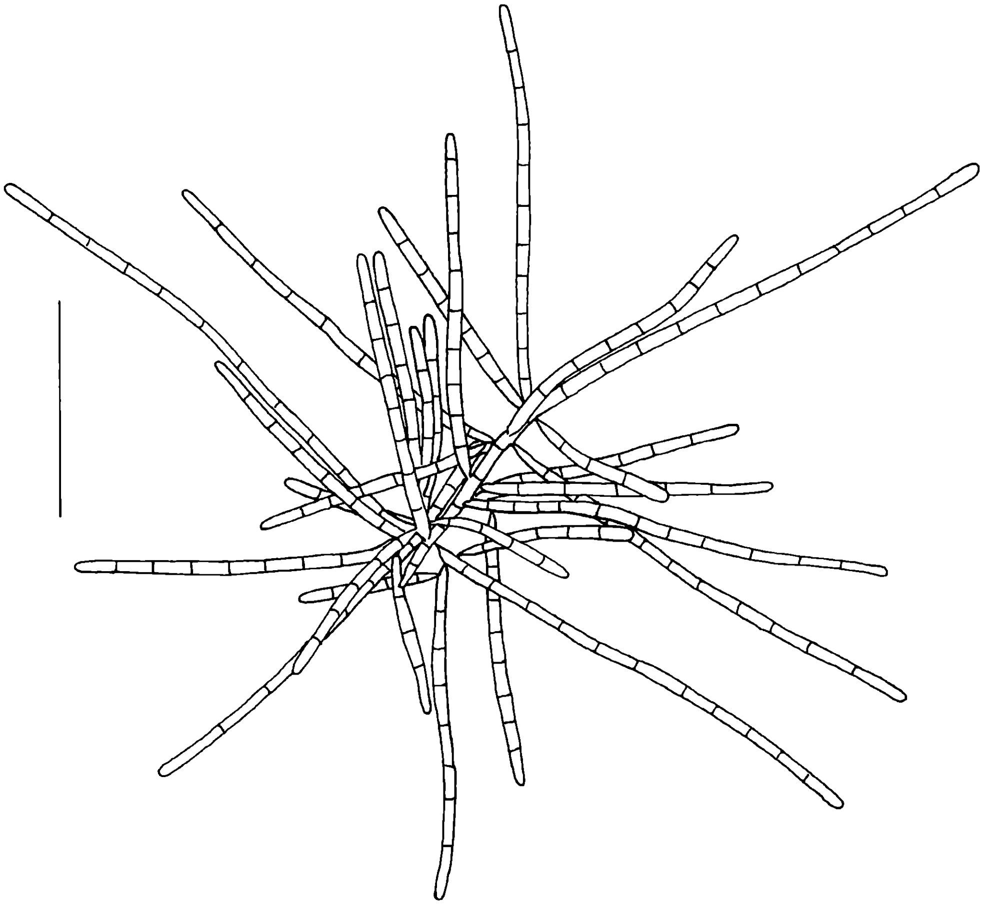

Fig. 15. *Dendrospora erecta*. Bar: 50 µm.