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Leptolyngbya sieminskae sp. n. (Cyanobacteria) from Svalbard

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Abstract: This paper describes in detail the phenotypic traits of the newly discovered *Leptolyngbya sieminskae* sp. n. (Cyanobacteria). The species was found at two islands of the Svalbard archipelago (Spitsbergen and Nordaustlandet) in habitats which differed in humidity, water sources and altitude. The research was conducted at two fjords: on the southern side of Spitsbergen – Hornsund (77°N, 015°E) and the north-west side of Nordaustlandet – Murchisonfjord (80°N, 018°E). Although *Leptolyngbya sieminskae* was found in different latitudes no significant morphological differences were found between the specimens from both sites. The only visible difference is in the thickness of filaments and sheaths.

Key words: Arctic, Hornsund, Murchisonfjord, blue-green algae, *Leptolyngbya*.

Introduction

Currently the description of new taxa is focused mostly on genotypic features but an information about phenotypic features and habitat conditions are also required for its full characteristics. The morphology of the species and the description of the biotope are key elements of field work and provide a basis for genetic research.

Literature data suggest (Kaštovská *et al*. 2005; Stibal *et al.* 2006; Matuła *et al.* 2007; Davydov 2008; Richter *et al.* 2009) that the cyanobacterial genus *Leptolyngbya* Anagn. *et* Kom., 1988 is widely distributed in numerous terrestrial habitats of Svalbard archipelago as: tundra soils, seepages, streams, puddles, lakes, moist rocks, snowfields and glacier surfaces. Stibal *et al*. (2006) recorded *Leptolyngbya* cf. *deliactula* (Compere) Anagn., *Leptolyngbya foveolarum* (Rabenh. ex Gom.) Anagn. *et* Kom., *Leptolyngbya hansgirgiana* Kom. in Anagn. and *Leptolyngbya* cf. *notata* (Schmidle) Anagn. *et* Kom. in three types of supraglacial sediment *e.g.*: cryoconite sediment, material from moraines and material from supraglacial kames near the snout in the lower part of four Svalbard glaciers in the vicinity of the Wrocław University *Stanisław Baranowski* Polar Field Station (Wedel Jarlsberg Land, West Spitsbergen). At Spitsbergen (Oscar II Land, Grønfjorden) also the following species were found: *Leptolyngbya foveolarum* and *L. notata* (Schmidle) Anagn. *et* Kom. (Davydov 2008). *Leptolyngbya boryana* Anagn. *et* Kom., *Leptolyngbya tenuis* (Gom.) Anagn. *et* Kom. were found in periglacial and subglacial soils on five glaciers near Ny-Ålesund (Kaštovská *et al.* 2005).

In the vicinity of the Hornsund fjord also other morphospecies were identified and described. They were: *Leptolyngbya bigranulata* (Gardnem) Anagn. *et* Kom., *L.* cf. *treleasii* (Gomont) Anagn. *et* Kom., *L.* cf. *margaretheana* (Schmid) Anagn. *et* Kom., *L.* cf. *valderiana* (Gomont) Anagn. *et* Kom., *L.* cf. *glacilis* (W. West *et* G.S. West) Anagn. *et* Kom. and *L. foveolarum* (Matuła *et al.* 2007; Richter *et al.* 2009).

Our research on cyanobacteria conducted between 2005 and 2011 confirms that the genus *Leptolyngbya* plays a significant role in shaping the habitable conditions for living organisms in the Svalbard archipelago. In many extreme terrestrial environments very low in nutrients in close proglacial sites, such as proglacial streams, barren soils, shallow ponds, but also in sites contrastingly high in phosphorus, nitrogen, chlorine or sodium in the vicinity of seabirds nesting colonies and in the coastal spray areas, *Leptolyngbya* were by far the most represented blue-green algae. They often grow as thick, leathery, nodular, slippery firm mats covering damp soils and stones or muddy bottoms of streams and lakes, where *Leptolyngbya* is a major constituent. They can also grow as tangled clusters or individual filaments immersed in gelatinous substance, creating various associations with other cyanobacteria, algae and mosses on large surfaces.

Field observations and the study of the abundant collected material allowed us to separate, using phenotypic markers, many morphospecies, whose features are not included in the descriptions of hitherto known taxa. This is true particularly for the *Leptolyngbya* genus. It may be that a part of them is specific for Svalbard, as is presented in this study of *Leptolyngbya sieminskae*.

Study area, material and methods

The material for this study was collected near the Hornsund fjord (West Spitsbergen) and on the northern side of Murchisonfjord (Nordaustlandet). Samples were collected during the Arctic summer in July and August between 2005 and 2011 (Hornsund Fjord) and in August 2009 (Murchisonfjord). Fig. 1 presents a detailed map of localities in the Hornsund fjord and Murchisonfjorden. Site positions, conditions and vegetation are given in Table 1. Fig. 2 presents the sites.

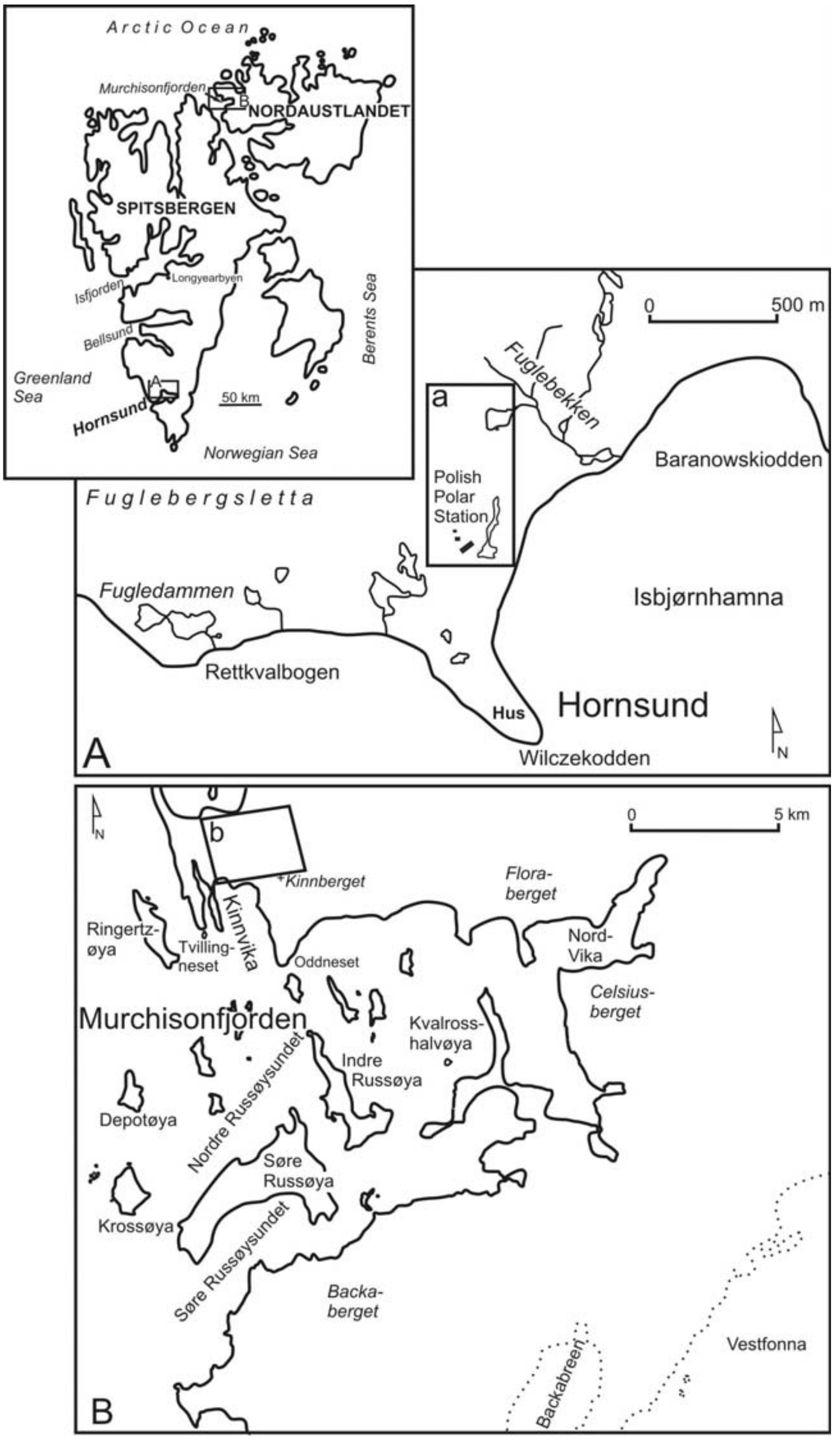

Fig. 1. Map of localities: in the Hornsund (**A**) and in the Murchisonfjorden (**B**).

Table 1

The descriptions of sites in study area.

Moisture	Site	Figs	Description	Latitude	Longitude	Elevation (m a.s.l.)
Hornsund						
moist	1	2a, b	moist *Saxifraga oppositifolia* community. Surfaces were supplied by snow melting water. Nodular cyanobacterial crusts were collected from mosses, soil, stones, gravel and sand	77°00' 11.5"	015°31' 55.0"	12
wet	2	2c	cyanobacterial mats in slowly streaming cold water and in the shallow water at the edge of a stream	77°00' 15.9"	015°3' 28.3"	6
moist	3	2d	cyanobacterial mats with mosses in *Saxifraga oppositifolia* community on a low slope, periodically supplied by streams water	77°00' 10.2"	015°32' 38.7"	7
wet	4	2e	shallow pond; cyanobacterial massive mats collected on the bottom from fine stones, sand and at the banks	77°00' 06.0"	015°32' 38.2"	2
moderate dry	5	2f, g	snowbed and surfaces with shallow hollows periodically supplied by rain water, covered with black and brown, thick ridge of cyanobacterial crust with *Anthelidium juretzkiana* and mosess	77°00' 13.4"	015°32' 42.7"	4
moist	6	–	massive cyanobacterial mats in water, on bottom, surface of stones and among growing mosses at the edge of seepages	77°00' 23.5"	015°33' 56.3"	8
moist wet	7	–	cyanobacterial mats in streams flowing though the mosses community marsh and in the shallow water at the edge of stream	77°00' 12.0"	015°32' 43.5"	3
Murchisonfjorden						
moist	8	2h, i	black and brown, thick ridge cyanobacterial crusts covering soil or fine stones, silt and among mosses; marsh near lake	80°03' 36.5"	018°13' 35.9"	36
wet	9	2j, k	snowbed with hollows and slightly patterned ground. periodically with shallow stagnant water; black thick cyanobacterial mats among stones and mosses	80°03' 24.4"	018°14' 55.3"	53

The described taxon can be found in different areas depending on a climate, and especially on temperature and the duration of the vegetation period. These differences depend on the latitudes *e.g.* 77° and 80°N.

The daily average air temperatures in July and August for Hornsund (77°N) between 1978 and 2006 were 4.4°C and 4.0°C, with maximal temperatures of 12.5–13.5°C (Marsz and Styszyńska 2007).

Nordaustlandet (80°03'N), where habitats 8 and 9 are located, is the northernmost island of the archipelago of Svalbard. The proximity of the polar ice cap and

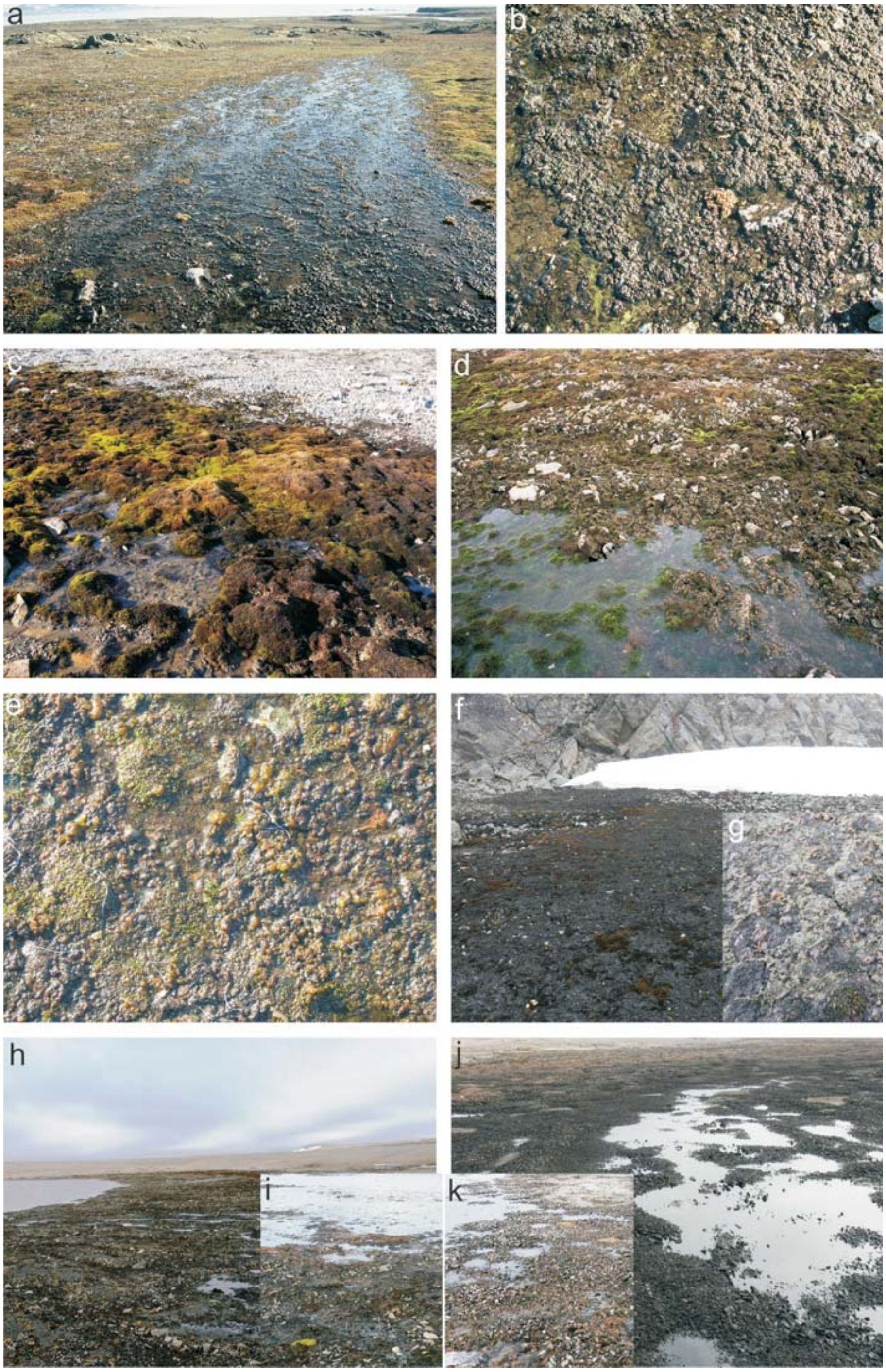

Fig. 2. Study area: **a**, **c**–**d**, **f**, **h**–**j**, habitats with the description in the text and Table 1; **b**, **e**, **g**, details of cyanobacterial crusts.

home of large Austfonna and Vestfonna glaciers contribute to long cold winters, short summers and cold growing seasons for terrestrial plants (Cooper 2011). The daily average soil surface temperatures near Swedish Research Station Kinnvika (Murchisonfjorden) ranged from 0–2°C in the period between 15th and 30th August 2007 (Cooper 2011 after S.J. Coulson – unpublished data). Also, Pohjola *et al.* (2011) describe similar monthly average air temperatures over the station in Kinnvika: 2.3, 2.5°C and 1.1, 1.5°C for July and August between 1957 and 1959 and between 2007 and 2009, respectively.

The above-mentioned differences in climatic conditions resulting from geographical distance are reflected by the vegetation in both locations.

The areas near the Hornsund fjord are covered by vascular plant communities, mosses and lichens, which are characteristic of the bio-climate zone of North Arctic tundra with an average July temperatures ranging from 3 to 5°C (CAVM Team 2003).

In harsh climatic conditions in non-glacial areas of Nordaustlandet (0–2.5°C) there is the scarce vascular plants vegetation characteristic of Arctic polar deserts (Neilson 1968; CAVM Team 2003; Cooper 2011). In both locations large deglaciated and snow-bed surfaces are covered by cyanobacterial crusts or associations of cyanobacteria with mosses. In contrast to vascular plants no differences in the composition of the taxa of the cyanobacterial communities (unpublished data) were observed in the studied localities.

Cyanobacterial crusts were scratched off from stones with a knife and then gathered together with mosses growing on the edges of water basins and in the soil. The samples were held in 100 ml plastic canisters. Microscopic observations were conducted on material preserved with the "etaform" (Starmach 1963). The preserved crusts were kept in darkness. Morphological observations were conducted with a digital microscope Nikon Eclipse 80i equipped with a Nikon DS-Fi1 Camera. The camera was calibrated for precise measurement of the size of the studied objects.

The taxa were archived using Lucia image analysis software to save the images and a scale of objects. The samples gathered in the field were preserved, marked, and stored in plastic containers in dark conditions. Along with the pictures they are stored in the Department of Botany and Plant Ecology of the Wrocław University of Environmental and Life Sciences.

Cyanobacteria were identified according to monographs by Komárek and Anagnostidis (1999, 2005).

Taxonomic description

Leptolyngbya sieminskae sp. n.
(Figs 3–9, Table 2)

Type material. — Samples are preserved and stored in plastic containers marked as: 82/2005, 40, 43, 49, 62, 93, II/2008, TK2, TK4/2009, TSM 1-3/2011 and banked in the Department of Botany and Plant Ecology of the Wrocław University of Environmental and Life Sciences.

Type locality. — Subaerophytic, on surface wet soil, stones, gravel and sand, in shallow water of hollows and shallow ponds or in streams flowing through the mosses and at the edge of streams and seepages.

Etymology. — The species is dedicated to Prof. Jadwiga Siemińska for her 65th anniversary of scientific career.

Characteristics. — The new morphospecies *Leptolyngbya sieminskae* always occurs along with other cyanobacteria as: *Gloeocapsa punctata* Nägeli, *G. kuetzingiana* Nägeli, *G. biformis* Ercegović, *Anathece clathrata* W. et G. S. West, *Leptolyngbya* spp., and *Schizothrix lacustris* A. Braun ex Gomont. It is variably shaped: flat, nodular or cylindrical and gray, pink, dark-brown and black, forming strong cyanobacterial crusts or amorphous gelatinous mats on the soil, stone and on the mosses. The structure of the *L. sieminskae* thallus is formed by single loosely spread (Figs 4a–d, 9b) or twisted together filaments (Figs 3c–f, 4e–f, 9b). Also, multi-filament structures can be found as densely entangled clusters (Figs 3a–b, 9a).

Individual filaments are straight, irregularly bent (Figs 3c–f; 4a–d, g) or twisted together (two or more) (Fig. 4e–f). The filaments are of different thickness depending on the thickness of the sheaths (Table 2).

The sheaths are homogeneous or consist of several layers of different thickness (Fig. 5d–g). On the surface they are smooth (Fig. 5o), waved (Fig. 6a, c–e) or ragged (Figs 5h–j, 6f–j), sometimes cuts shaped as muffs appear on the trichomes (Figs 5k–l, 6l–n). On the tips they are shaped as evenly cut cylinders, a broad funnel or are ragged (Figs 5h–j, m–n, o; 6k; 9i–k). Sometimes the sheaths unveil the cylindrical inner layers which cause the gradual decrease in filaments' thickness (Figs 5d–g; 9c, h). Sheaths are usually open at the ends. (Fig. 6a, c–e). Sometimes the sheaths are covered with thin, colourless coat made by the gelatinisation of their edges.

Table 2

The size analysis (μm) of *Leptolyngbya sieminskae* sp. n. filaments and trichome.

Features		Minimal values	The most frequent values	Maximal values
Location: Hornsund (77°N, 015°E)				
filaments	width	2.29	2.7-3.0-4.0-4.8	5.93
cells	length	1.37	1.5-2.0-2.5-2.8	3.28
	width	0.86	1.0-1.2-1.4-1.5	1.94
	L/W ratio	1.53:1	1.6-1.8:1	2.13:1
Location: Murchisonfjorden (80°N, 018°E)				
filaments	width	2.77	3.0-3.5-4.5-5.5	6.21
cells	length	1.22	1.5-2.0-2.7-3.0	3.83
	width	1.02	1.1-1.3-1.5-1.6	1.95
	L/W ratio	1.16:1	1.4-1.6:1	1.82:1

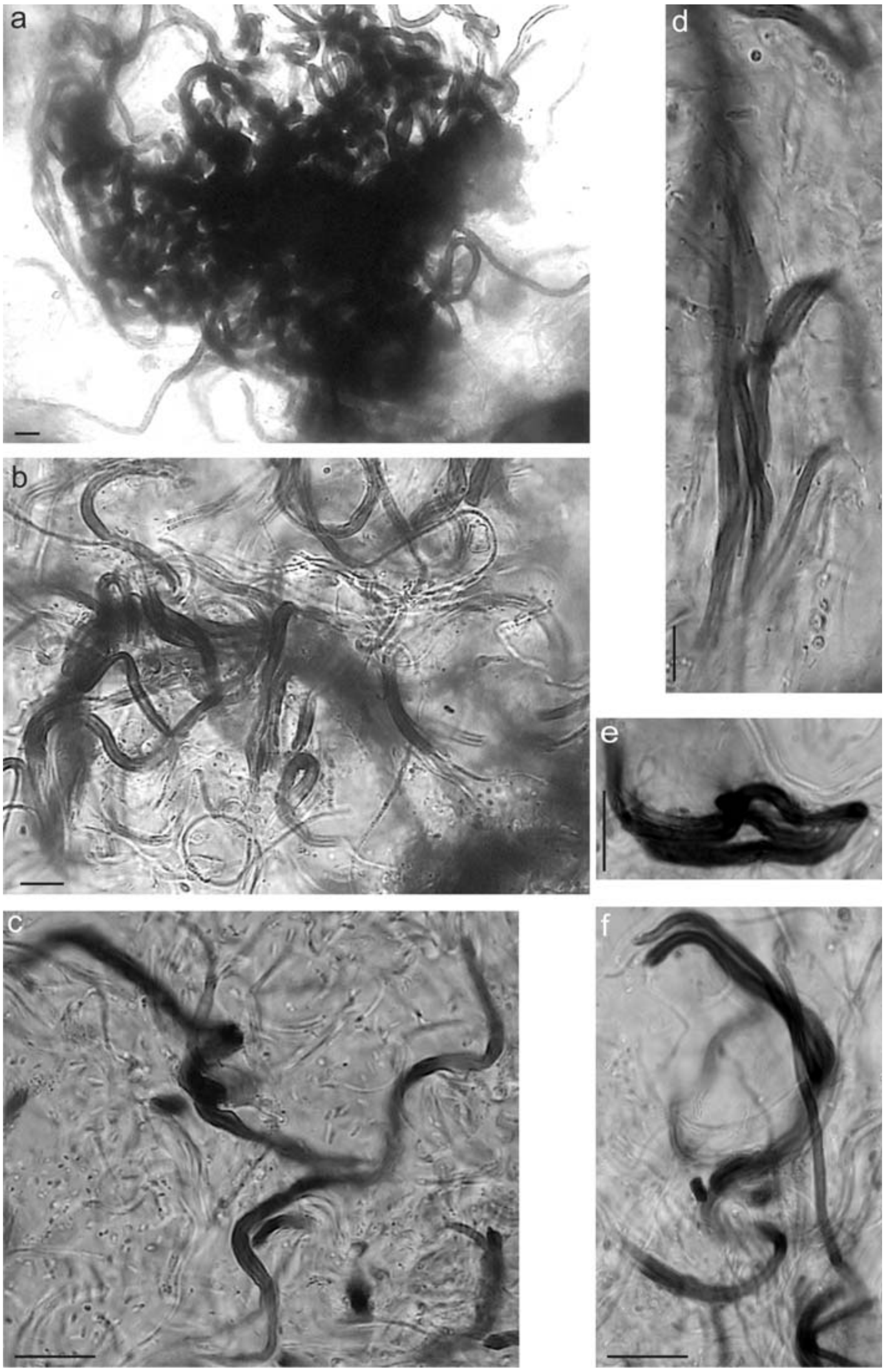

Fig. 3. Thallus of *Leptolyngbya sieminskae* sp. n. from Hornsund: **a**–**b**, entangled multi-filament clusters; **c**–**f**, individual, loosely spread or with a few filaments entangled together. Scale bars 10 µm.

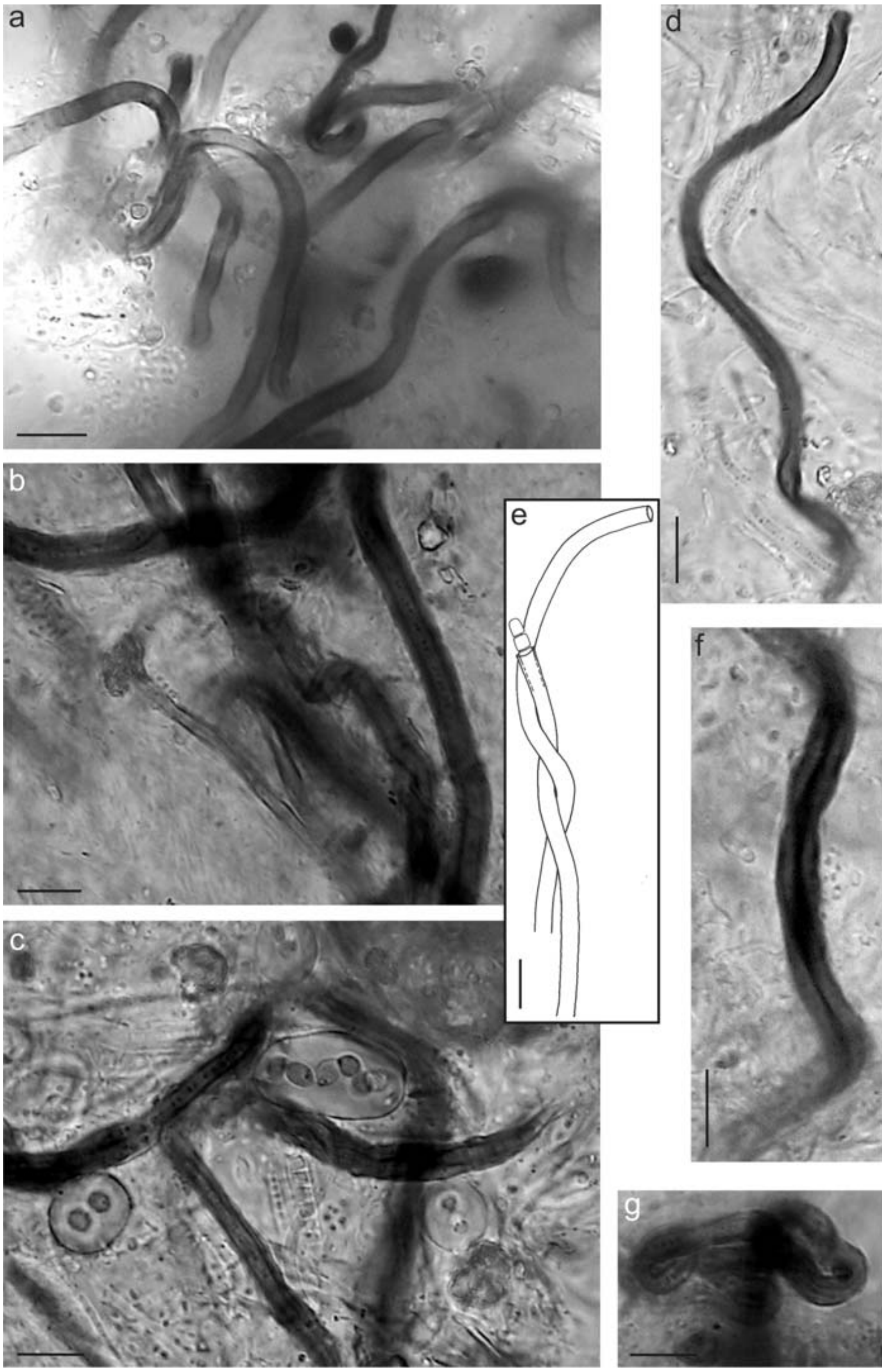

Fig. 4. Thallus of *Leptolyngbya sieminskae* sp. n. from Murchisonfjorden: **a–c**, loosely entangled filaments; **d**, wavy and curved single filament; **e–f**, filaments twisted together; **g**, irregularly coiled filament. Scale bars 10 μm.

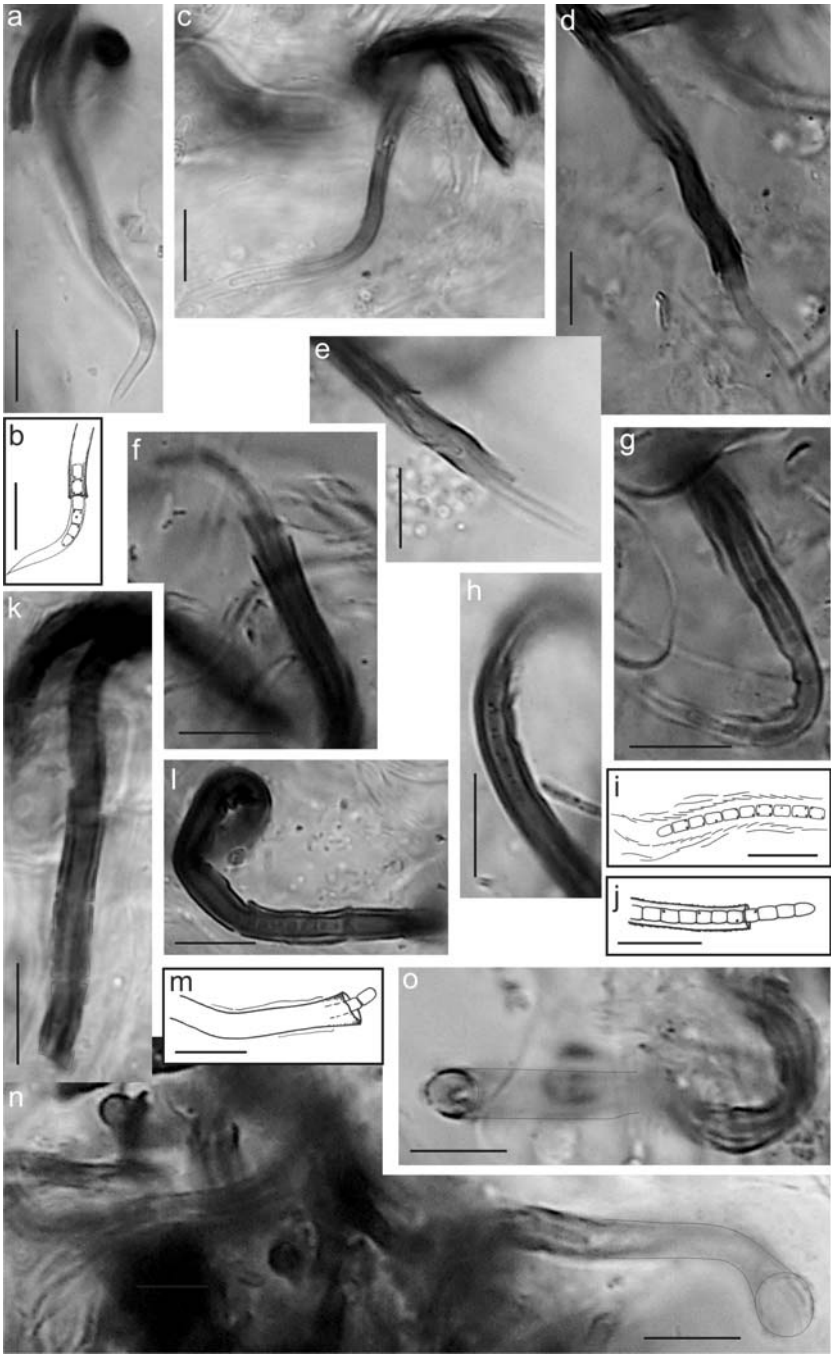

Fig. 5. Sheaths of *Leptolyngbya sieminskae* sp. n. from Hornsund: **a**–**c**, ends of sheaths less coloured and closed; **d–g,** sheaths gradually revealing the cylindrical inside layers; **h–j**, edges of the sheath tattered; **k**–**l**, cylindrical sheaths shaped like muffs; **m**–**n**, end of sheaths shaped like a funnel; **o**, cylindrical sheath with smooth edges. Scale bars 10 µm.

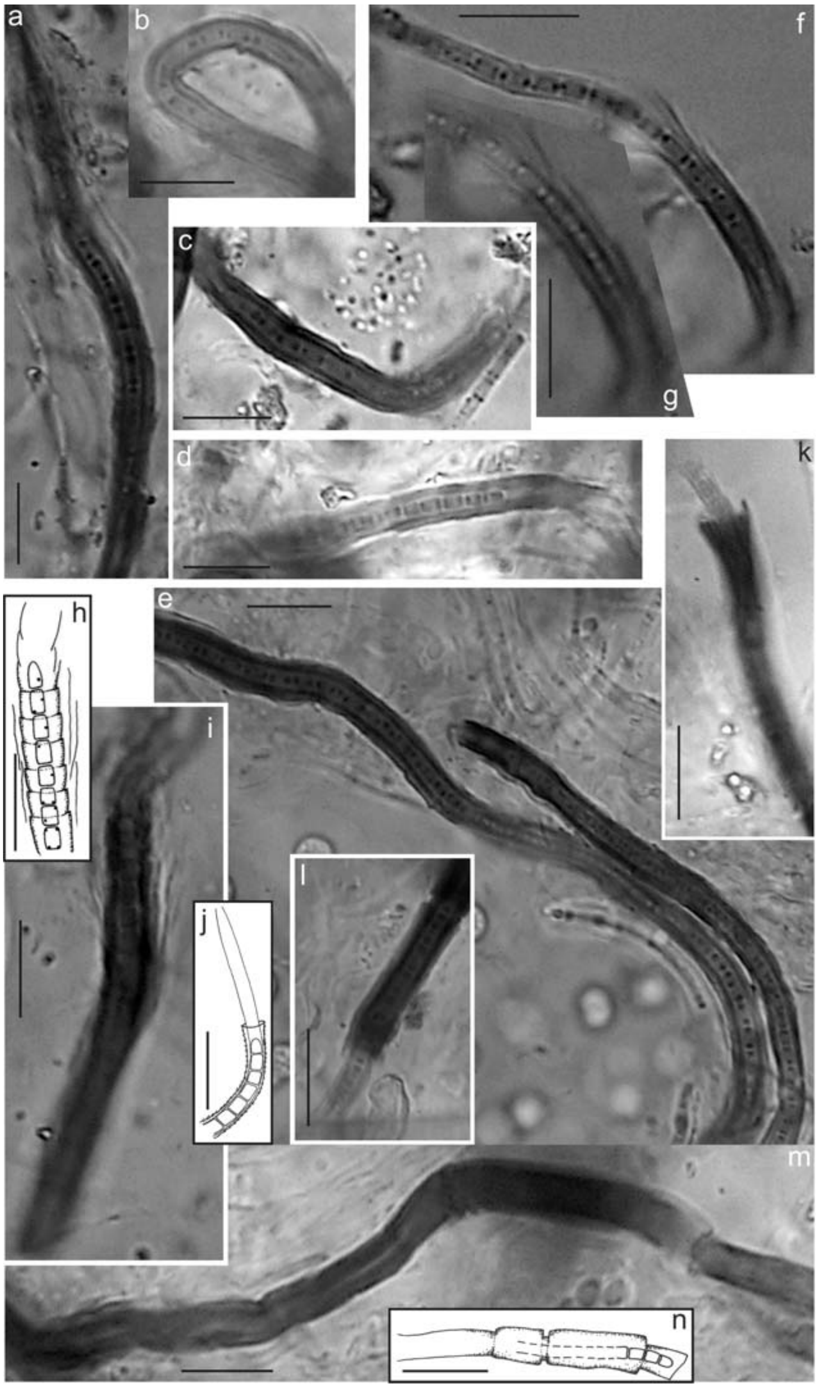

Fig. 6. The sheaths of *Leptolyngbya sieminskae* sp. n. from Murchisonfjorden: **a**, **c**–**e**, firm sheaths, wavy on edges; **b**, **f**–**j**, scaly sheath edges; **k**, funnel-shaped sheath end tip?; **l**–**n**, cylindrical sheaths shaped like muffs. Scale bars 10 µm.

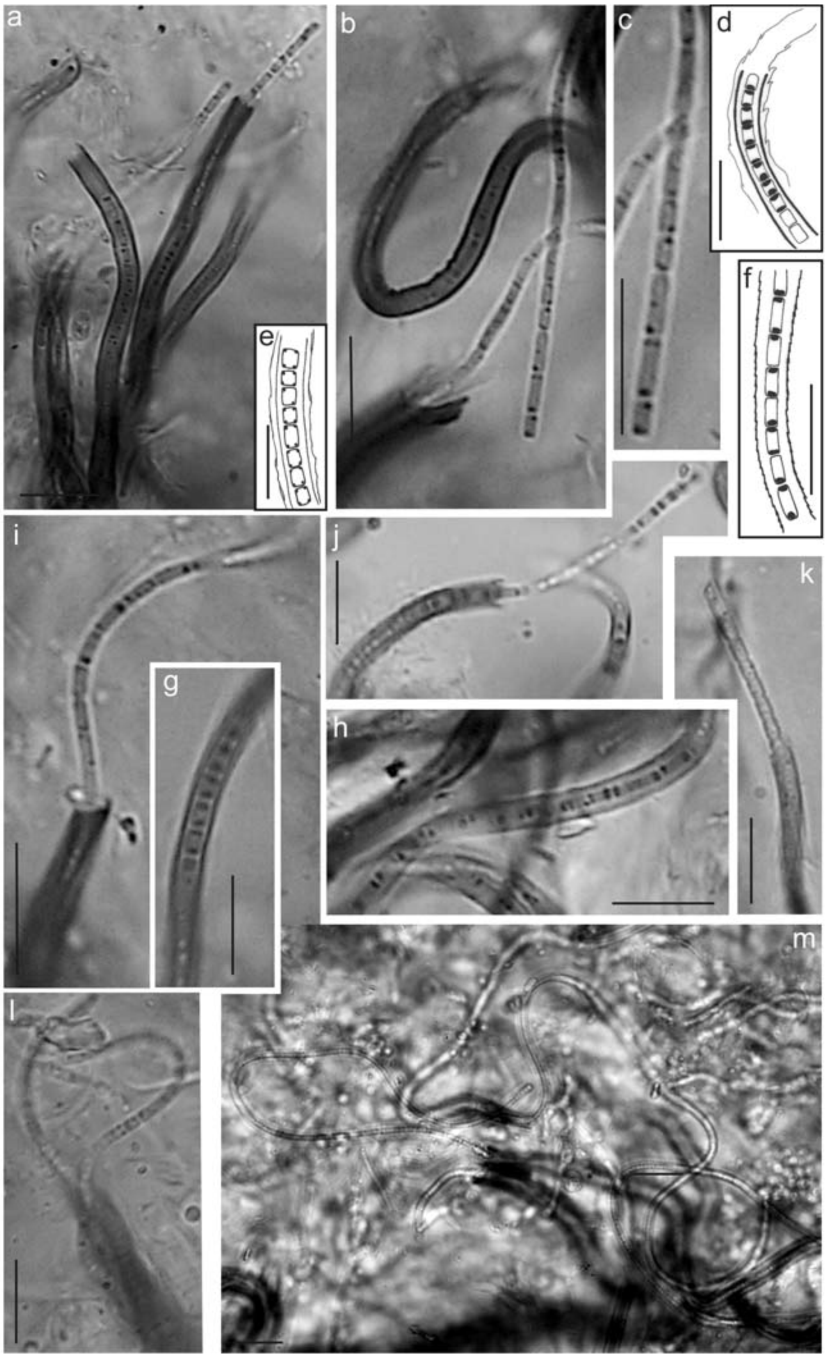

Fig. 7. Morphology of filaments and trichomes of *Leptolyngbya sieminskae* sp. n. cells from Hornsund: **a**–**b**, **i**–**j**, end of trichomes with sheaths; **c**–**h**, details of trichomes, square and rectangular cells; **k**, the end of trichome with barrel-shaped cells; **l**–**m**, long trichomes coming out of sheaths. Scale bars 10 μm.

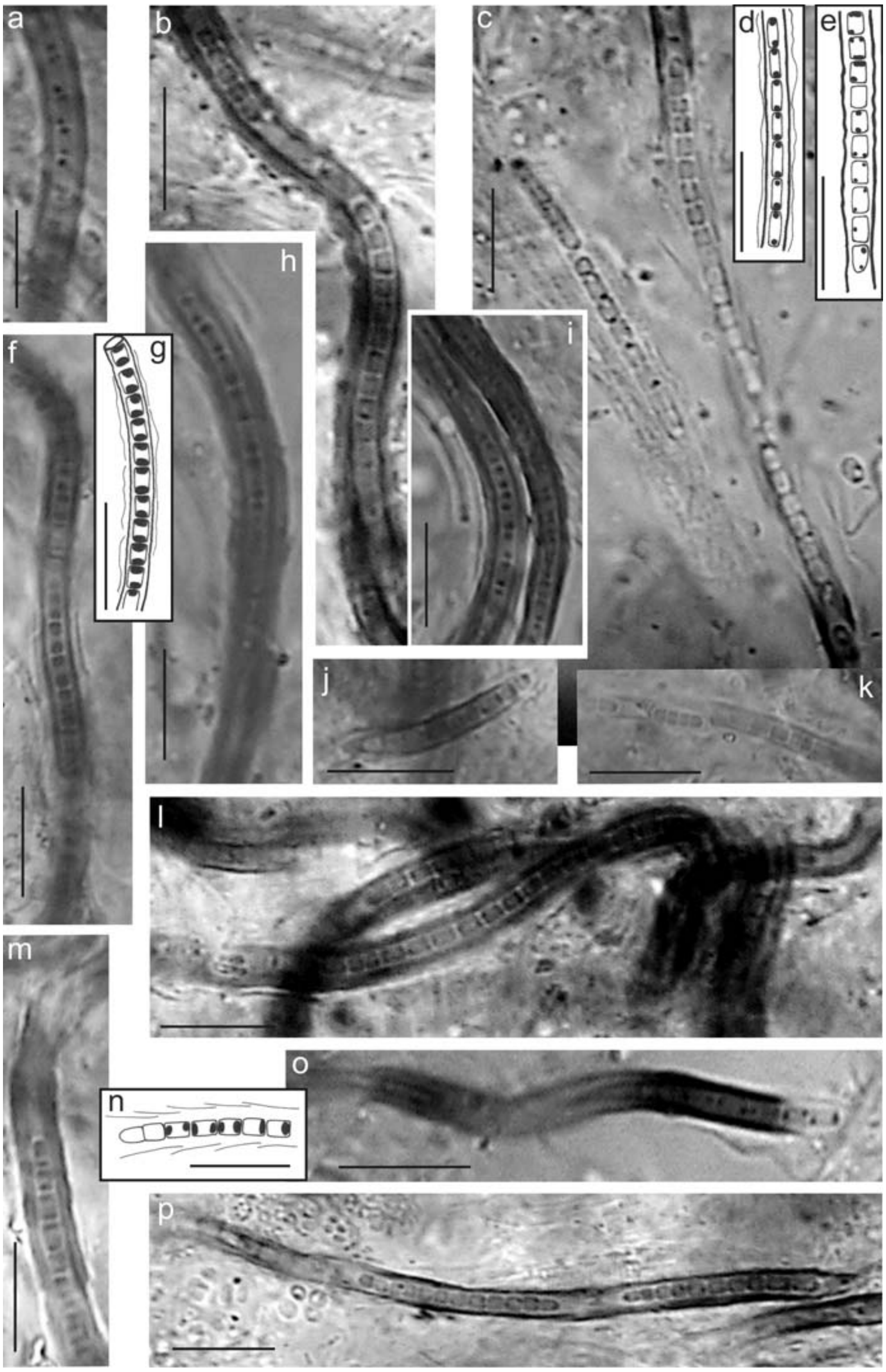

Fig. 8. Morphology of filaments and trichomes of *Leptolyngbya sieminskae* sp. n. from Murchisonfjorden: **a**–**b**, **d**–**i**, **l**–**o**, square and rectangular cells; **j**–**k**, hormogonia; **c**, **p**, filament with hormogonia. Scale bars 10 µm.

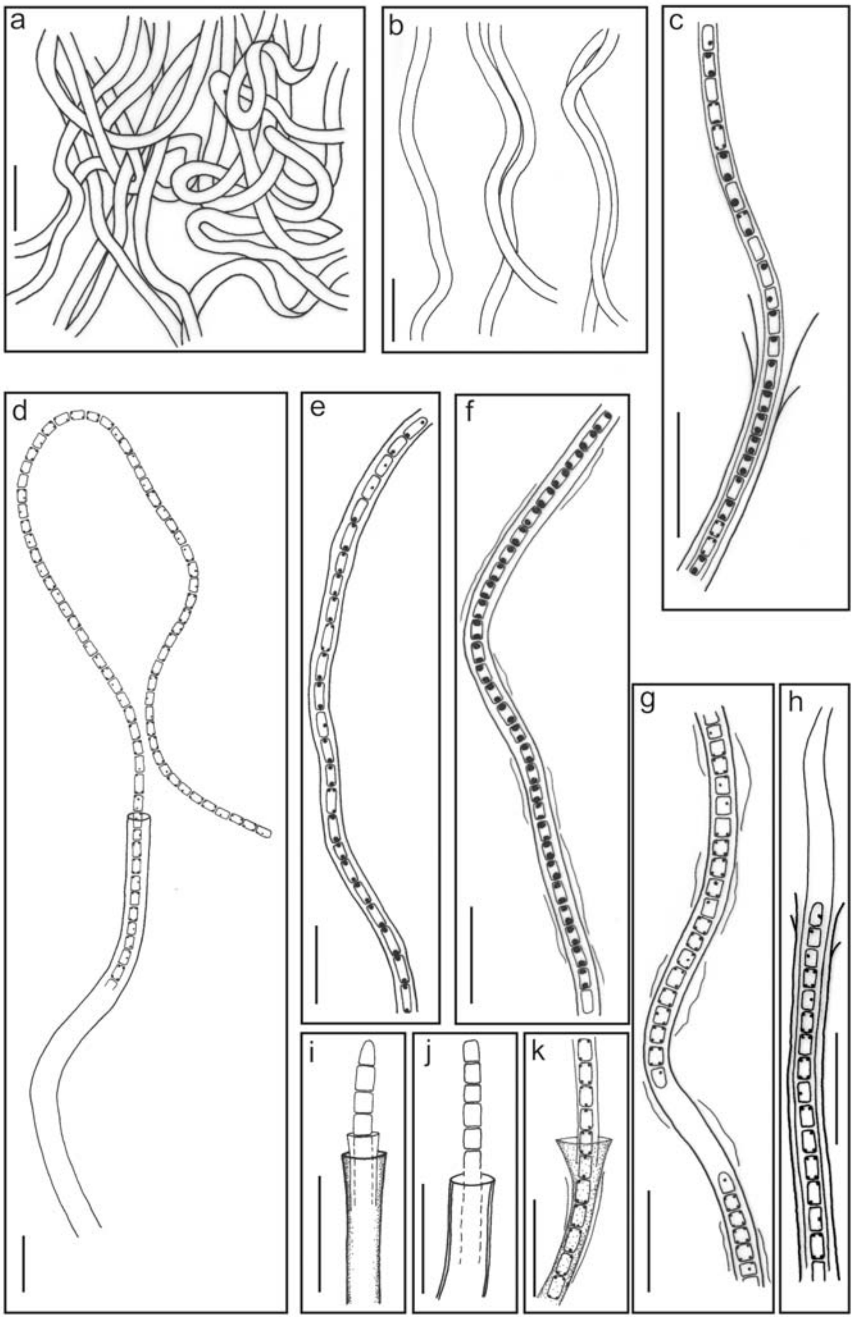

Fig. 9. Morphology of thallus, filaments and trichomes of *Leptolyngbya sieminskae* sp. n.: **a**, entangled multi-filament clusters; **b,** individual, loosely spread or entangled filaments; **c**, **h**, sheaths ragged at the ends, uncovering inside layers; **d,** long trichome coming out of sheath; **c**, **e**–**h**, details of trichomes, square and rectangular cells; **i**–**j**, details of sheaths; **i**, funnel-shape end of sheath; **j**, cylindrical end of sheath; **k**, funnel-shape and spread end of sheath. Scale bars 10 μm.

The sheaths vary from light- and dark-violet/navy blue to light- and dark-brown/black. Some are slightly less coloured towards ends, several even completely colourless (Fig. 5a–c).

The trichomes are pale blue-green, constricted at the translucent cross-walls. The cells are square (isodiametric) or rectangular with rounded ends, sometimes barrel-shaped (Figs 7a–m; 8a–b, d–I, l–o; 9c, e–h). The cells mostly are of (1.16) 1.4 to 1.8 (2.13) length to width ratio. In some trichomes cells of varying size were observed. The cells have a varying number of different-size granulations, most commonly one or two granules at the cell‘s end (Figs 7a–j, l; 8a–i, l–p). Granules as big as the width of the trichome take over a half of the cell (Figs 7d, g, j; 8f–g, n). Apical cells are rounded or slightly narrowed.

Latitude and resulting climatic differences do not have a significant influence on the shapes and sizes of trichome cells gathered in the studied locations (Table 2). The only differences between the *L. sieminskae* collected from Hornsund and Murchisenfjorden areas were in the thickness of filaments, which results from different sheaths‘ width.

Ecology. — Subaerophytic, on surface wet soil, stones, gravel, and sand, in shallow water of hollows and shallow ponds or in streams flowing though the mosses and at the edge of stream and seepages.

Discussion

Leptolyngbya sieminskae sp. n. was discovered in two geographically distinct localities which are different in climatic conditions *e.g.*: average air temperatures in growing seasons, the length and severity of winters, and the length and temperature of the vegetation period. As a consequence, the temperature differences may also occur in micro-habitats. Other ecological conditions, including humidity, mobility, the type of water or nutrient availability were similar.

One could assume that the temperature differences are significantly reduced by the cyanobacteria ability to accumulate warmth (due to protective dye). Cyanobacteria are also known to be very uniform and versatile. These properties of cyanobacteria undoubtedly caused the lack of important phenotypical differences between Hornsund and Murchisonfjorden *L. sieminskae* populations. The only differences between the *L. sieminskae* collected from Hornsund and Murchisonfjorden areas were in the thickness of filaments, which results from different sheaths’ width. This is perhaps caused by the slightly colder climate near Murchisonfjorden.

Vascular plants react differently to climatic differences. Both locations had plant life strictly linked to the bioclimatic zones; in this case two tundra types – Arctic Polar Deserts and North Arctic tundra.

The new taxon was described only with regard to phenotypical characteristics and the observations were based on field samples.

So far the data on the genotypic characteristics of cyanobacteria from Svalbard are scarce. Comte *et al.* (2007) and Strunecký *et al.* (2011) discussed the genotypic similarities and differences of *Phormidium* from Svalbard and from Antarctica.

Although today mostly genotypic characteristics are recommended in describing new taxa (Whitton 2002; Taton *et al.* 2003) a full characteristics requires detail information about phenotypical features and ecology. Komárek (2007, 2010) strongly emphasizes the significance of molecular analyses in discovering the phylogenesis of cyanobacteria and the importance of morphological and ecological characteristics.

It is known that phenotypical and genotypical features are not always correlated and that within the same ecotypes there is a wider genetic diversification than within phenotypes. These problems in cyanobacteria taxonomy in Antarctica were also emphasized by Komárek (2007).

Additionally, in our opinion, an earlier identification of morpho- and ecotypes of cyanobacteria occurring in the given area provides a good base for molecular research. Well described phenotypical markers distinguishing taxa are essential in the studies of their biodiversity, ecology and role in the environment. However, only a precise description of the phenotypical and genotypical features of cyanobacteria provides a full image of their taxonomic diversity. It also explains the phylogenetic relations between taxa and their origins.

Leptolyngbya sieminskae sp. n., despite several significant differences, resembles *L. nigrescens* Komárek, an endemic Antarctic species. The filaments and mats are physiognomically similar (the colour and shape of the sheaths, the characteristic diagonal layers or irregularly scaled edges of the sheaths). It shows, however, significant differences in the structure of filaments and in the shape and dimensions of the cells. *Lyngbya fusco–vaginata* described by Starmach (1995) from Enderby Land (East Antarctic) and above mentioned *L. nigrescens* show the similarity to *L. sieminskae*, especially in the external structure of the filaments e.g. colour and shape of the sheaths. The difference in cell shape and size is, however, substantial. Additionally, *Lyngbya fusco–vaginata* is almost identical with *L. nigrescens*, but both taxa differ slightly in cell size.

Considering certain similarities between *Leptolyngbya sieminskae* from Svalbard and *L. nigricans* and *L. fusco–vaginata* from Antarctica one could conclude that they are vicarious.

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Project (2005– 2007): Biosphere – Structure, Evolution and Dynamics of Litosphere, Cryosphere and Biosphere in Arctic and Antarctic (PBZ-KBN-108/PO4/2004), TOPOCLIM KBN 113/IPY/2007/ 01/f. and IPY project 58-Kinnvika: "Change and variability of Arctic System, with focus on Nordaustlandet, Svalbard".

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