Diversity of *Aphanizomenon*-like cyanobacteria.

Diverzita sinic z okruhu rodu *Aphanizomenon.*

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Abstract

The cyanobacterial filamentous, heterocytous and planktic genus *Aphanizomenon* is heterogeneous according to both, molecular and morphological criteria. Using combined "polyphasic" method for evaluation of its natural diversity, the close genetic relation to planktic *Anabaena* was recognised. However, the different clusters within the genus *Aphanizomenon* are separated one from another as well as similar subclusters of planktic *Anabaena* (cf. literature cited). The subclusters are well characterised also according to phenotype markers. In the present review the diversity of the traditional genus *Aphanizomenon* according to recent state of knowledge is demonstrated. The form-genera *Aphanizomenon* sensu stricto (type-species *Aph. flos-aquae*) and *Cuspidothrix* (type-species *C. issatschenkoi*) are reviewed in more detail.

Introduction

The cyanobacterial freshwater and planktic genus *Aphanizomenon* MORR. ex BORN. et FLAH. (type species: *Aph. flos-aquae*) has been found heterogeneous during last years. The molecular method of 16S rRNA sequencing proved a very close relation of this form-genus (with obligatory or facultative occurrence of gas vesicles in the cells) to planktic types (morphospecies) of *Anabaena* (subg. *Dolichospermum* (RALFS ex BORN. et FLAH.) KOM. et ANAGN.; type-species = *Anabaena flos-aquae*). Therefore, in future, this planktic cluster of *Anabaena* must be separated from the typical benthic or terrestrial *Anabaena* BORY ex BORN. et FLAH. (with the type-species *Anabaena oscillarioides*); (cf. ITEMAN et al. 2002, GUGGER et al. 2002 a, 2002b, RAJANIEMI et al. 2005a, 2005b, WILLAME et al. 2006, etc.). However, a more uniform, planktic *Anabaena/Aphanizomenon* cluster contains several subclusters, which can be separated and recognised clearly morphologically after more complex evaluation (Li et al. 2003, Rajaniemi et al. 2005b, Willame et al. 2006). The genus *Aphanizomenon* sensu stricto particularly can be clearly defined according to stable phenotypic and biochemical criteria, and several taxonomic units on the generic level could be expected within this whole cyanobacterial group. The limit 95% of similarity is considered as main criterion for generic separation in bacteriological taxonomy (Stackebrand & Goebel 1994, Wayne et al. 1987), and genetic similarity between the subclusters of planktic *Anabaena* and *Aphanizomenon* is just near to this limit (slightly below or above, according to different evaluations). The phenotypic separation of different *Aphanizomenon*-subclusters indicates particularly wider diversity. The present state of taxonomic relations of the traditional genus *Aphanizomenon* is summarised in this article, as a basic review for the next studies.

Results

Molecular and combined evaluation

The genetic evaluation should be the basic criterion for taxonomic classification of cyanobacteria. The close relations of *Aphanizomenon* to planktic *Anabaena*-species (= subg. *Dolichospermum*) ensue from all recent molecular analyses (Iteman et al. 2002, Gugger et al. 2002a, 2002b, Rajaniemi et al. 2005a, 2005b, Willame et al. 2006; see Figs 1-2). The name *Aphanizomenon* should be used as the valid name for this whole large polymorphic group containing all planktonic *Anabaena* and *Aphanizomenon* morphospecies, if the whole cluster is classified as a unique generic taxon. However, this group is phenotypically diversified to such a degree, that the classification into different generic units is justifiable according to combined criteria (Figs 3-4). At least, four different morphological groups are recognisable in the traditional genus *Aphanizomenon* (*Aph. flos-aquae, Aph. gracile, Aph. issatschenkoi* and *Aph. volzii* – subclusters), which belong to delimited morphotypes with similarity about (or less than) 95%.

Phenotype diversity

The typical part of the genus *Aphanizomenon* (morphotype **A** – p. 7; *Aph. flos-aquae* and related morphospecies: *Aph. klebahnii, Aph. yezoense, Aph. flexuosum,*etc.) represents evidently the stable, characteristic and well phenotypically delimited morphotype, characterised by the tendency to form fascicles of trichomes with mostly cylindrical cells, not or slightly narrowed towards ends, and with elongated and ± hyaline apical cells. The end cells are “cut” or rounded. From this group, the clusters of *Aph. gracile* (morphotype **B** –

p. 16; trichomes solitary, narrowed towards ends; terminal cells not or indistinctly lengthened; apical cells sometimes morphologically modified) and of *Aph. issatschenkoi* (morphotype **C** – p. 23; apical cells lengthened and ± pointed, hyaline) can be clearly separated. The last cluster has been already separated by RAJANIEMI et al. (2005b), as a special generic entity, i.e. genus *Cuspidothrix*. If the cluster of *Aph. gracile* is classified as a separated generic unit, several morphospecies, originally described as *Anabaena*, should be probably classified also into this generic unit according to morphological similarity ("transitional" group between planktic Anabaenas with ± straight trichomes and *Aph. gracile*).

A small group of "*Anabaena volzii*" with ± symmetric structure of trichomes and narrowed ends must be considered also a special *Aphanizomenon* morphotype (**D,** p. 26). This species has been transferred already to the genus *Aphanizomenon* by KOMÁREK (1984a) just according to the almost symmetric structure of filaments. However, its position must be verified by molecular methods. A special generic entity is probable for this cyanobacterial morphotype.

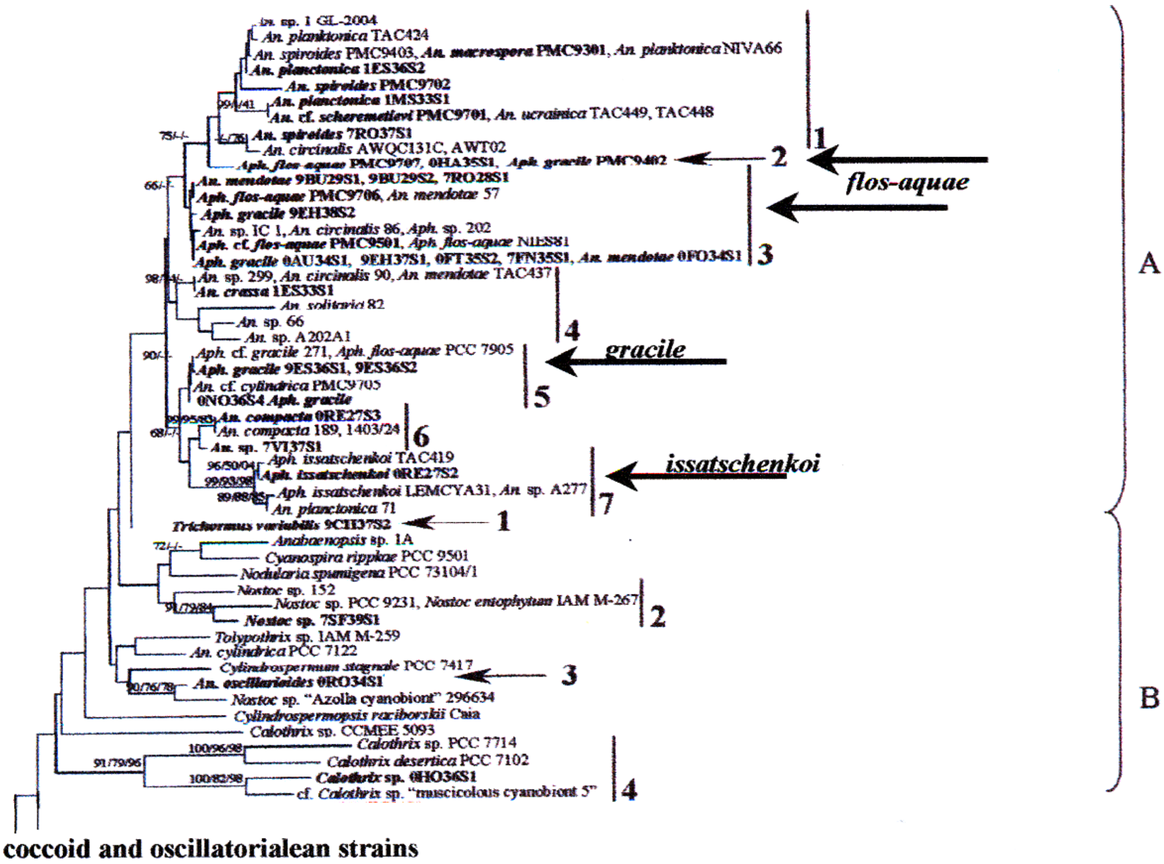


Fig. 1: Part of the phylogenetic tree (heterocytous cyanobacteria), illustrating the heterogeneity of the genus *Aphanizomenon* (thick arrows; the identification of several strains is problematic); A = planktic strains with gas vesicles, B = strains without gas vesicles. – After GUGGER et al. (2002a).

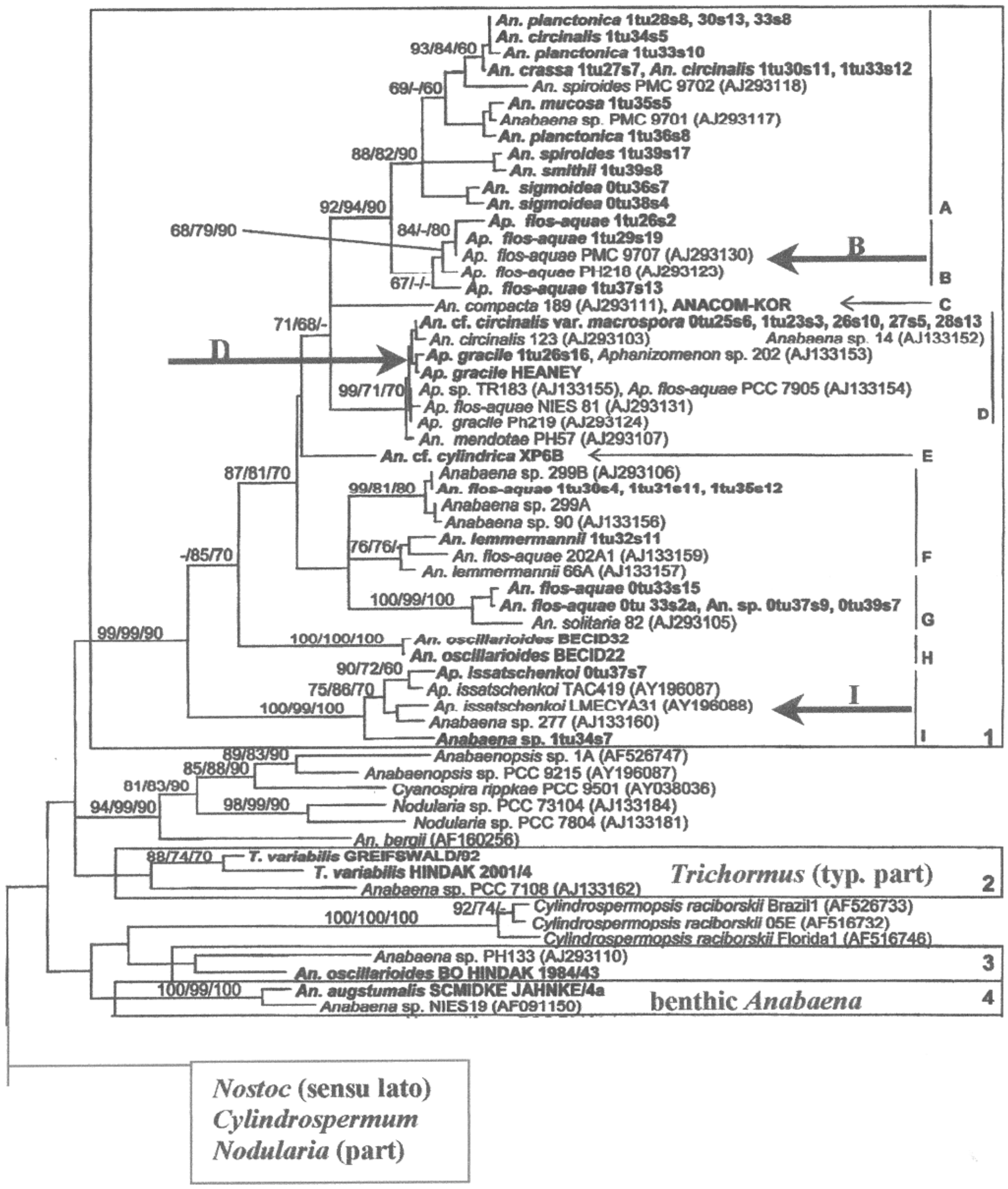


Fig. 2: Part of the phylogenetic tree, illustrating the close relations of all planktic *Anabaena*- and *Aphanizomenon*-strains (cluster 1). Different subclusters of *Aphanizomenon* are separated and divided in several subclusters, distant one from another (thick arrows): B = typical *Aph. flos-aquae*, D = *Aph. gracile*, I = *Aph. issatschenkoi* (= *Cuspidothrix*).
– After RAJANIEMI et al.(2005a).

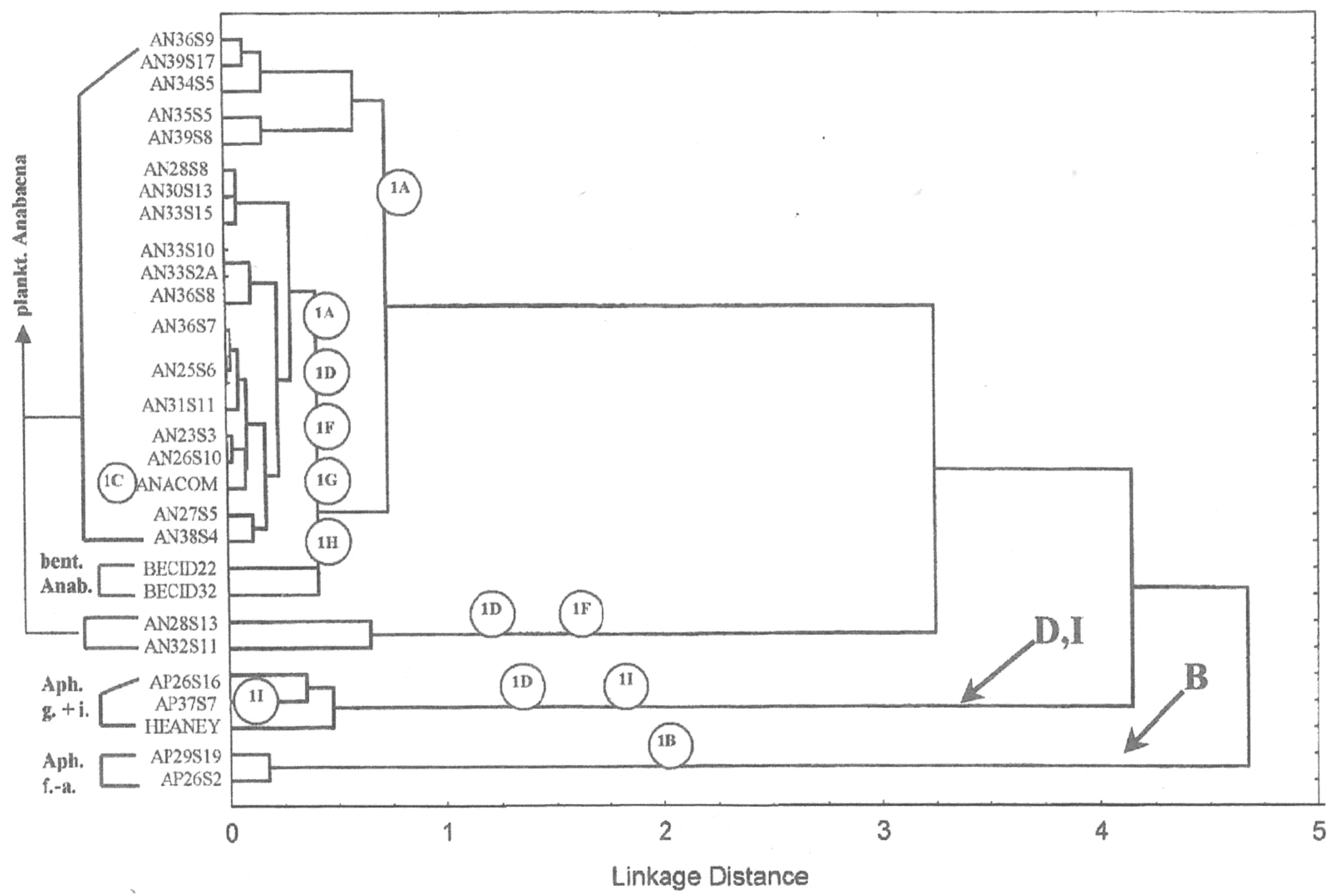


Fig. 3: Combined evaluation (cluster analysis) of planktic *Anabaena* and *Aphanizomenon* strains (molecular + phenotype + bioch emical characters). The *Aphanizomenon* subclusters represent clearly separated units; B = typical *Aph. flos-aquae*; D,I = line containing subclusters with two related strains of *Aph. issatschenkoi* and one strain of *Aph. gracile*. – After RAJANIEMI et al. (2005b).

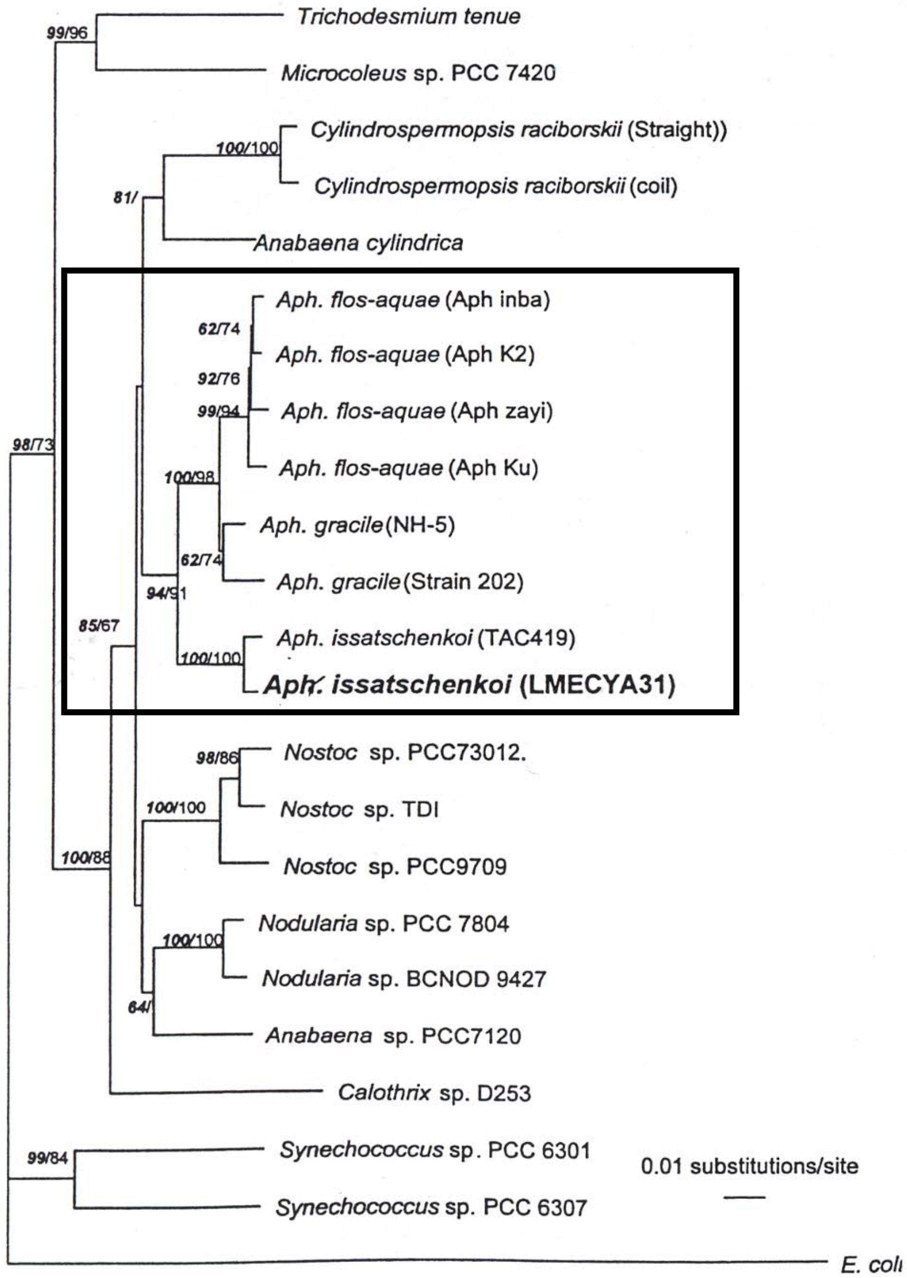


Fig. 4: Diversity of strains inside the traditional genus *Aphanizomenon*. – After LI et al. (2003).

Taxonomic review

(**A**) Form-genus ***Aphanizomenon*** MORR. ex BORN. et FLAH., Ann Sci. Nat. 7, ser. 7: 241, 1888 (Fig. 5).
Syn.: *Aphanizomenon* MORR., Mém. Acad. Roy. Belg. 11: 11, 1838 (pre-starting-point syn.).

Trichomes free-floating or metaphytic, ± straight, slightly curved or flexuous, rarely solitary, with tendency to form fascicles, where they are parallelly arranged, without sheaths and only sometimes with a very fine, indistinct slime, not constricted or slightly constricted at cross walls, not or very slightly narrowed towards ends. Cells cylindrical, ± isodiametric or slightly longer or shorter than wide, rarely barrel-shaped, to the ends elongated, obligatory with gas vesicles; terminal cells (old trichomes!) several times longer than wide, with hyaline or almost hyaline content, at the end rounded or flattened. Heterocytes exclusively intercalar (only after disintegration the terminal position is possible), ± cylindrical, of the same width as vegetative cells, usually 1, rarely 2(-4) in one trichome. Akinetes intercalar, cylindrical (in one species almost spherical), solitary or very rarely (exceptionally) in pairs, distant from heterocytes, several times larger than vegetative cells, developing after fusion of several vegetative cells; only one akinete develops in one trichome. Trichomes have subsymmetric structure.

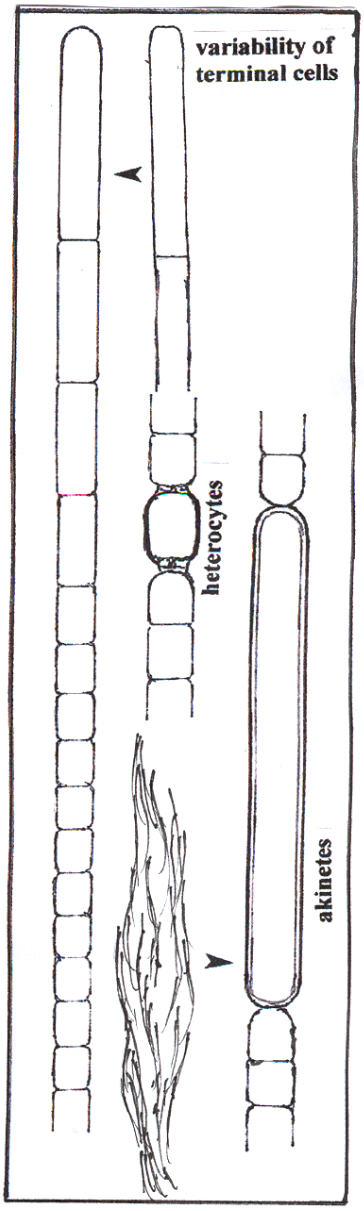


Fig. 5: After RAJANIEMI et al. (2005b)

List of species:

- ***Aphanizomenon flos-aquae*** RALFS ex BORN. et FLAH., Ann. Sci. Nat. – Bot., ser. 7, 7: 241, 1888. (Figs 6, 8)
  Syn.: *Aphanizomenon incurvum* MORR., Mém. Acad. Roy. Sci. Belg. 11: 11, 1835; (pre-start.-point).
  Aphanizomenon cyaneum RALFS, Ann. Mag. Nat. Hist., ser. 2, 5: 341, 1850; (pre-start.-point).
  Aphanizomenon holsaticum RICHT., Hedwigia 35: 273, 1896; incl.

Aphanizomenon americanum REINH., Bull. Torrey Bot. Club 68: 328, 1941; incl.

- ***Aphanizomenon klebahnii*** (ELENK.) PECHAR et KALINA, Algolog. Stud., in press. (Figs 7, 8)
  Syn.: *Aphanizomenon flos-aquae* var. *klebahnii* ELENK., Izv. Imper. S.-Petersb. Bot. Sada 9: 147, 151, 1909.
  Aphanizomenon klebahnii ELENK., Izv. Imper. S.-Petersb. Bot. Sada 9: 148, 1909; (nom. alternat.).
- ***Aphanizomenon yezoense*** M. WATAN., Bull. Nat. Sci. Mus., ser. B, 17 (4): 150, 1991. (Fig. 9)
- ***Aphanizomenon paraflexuosum*** M. WATAN., Bull. Nat. Sci. Mus., ser. B, 17 (4): 148, 1991. (Fig. 10)
- ***Aphanizomenon flexuosum*** KOM. et KOVÁČIK, Pl. Syst. Evol. 164: 54, 1991. (Fig. 11)
- ***Aphanizomenon slovenicum*** REKAR et HINDÁK, Ann. Limnol. 38 (4): 275, 2002. (Fig. 12)
- ***Aphanizomenon platense*** SECKT, Bol. Acad. Nac. Cienc. Cordoba 25: 421, 1922. (Fig. 13)
- ***Aphanizomenon hungaricum*** KOM.-LEGN. et MÁTYÁS, Arch. Protistenk. 145: 25, 1995. (Fig. 14)

Notes:

- Special *Aphanizomenon* eco- and morphospecies from the vicinity of *Aph. flos-aquae/Aph.klebahnii* occurs in Baltic Sea. This type should be described in future (PECHAR & CRONBERG, pers. comm.).
- Several varieties and forms of *Aphanizomenon flos-aquae* were described, the taxonomic position of which is unclear (var. *hercynicum* KÜTZ. ex FORTI 1907, var. *haerdtlii* FJERD. 1966, f. *incurvatum* ČERNOV 1950, f. *macrosporum* FEDOR. 1970).
- Following species were excluded from the genus *Aphanizomenon*:
  Aphanizomenon kaufmannii SCHMIDLE 1897 = *Cylindrospermopsis raciborskii* (WOŁOSZ.) SEENAYYA et SUBBA RAJU 1972.
  Five species, transferred into the genus *Cuspidothrix* see on p. 23-25.
- *Anabaena affinis*, forming fascicles of trichomes, belongs possibly also into this cluster.

Key (main diacritical features of typical *Aphanizomenon* – morphospecies):

Aphanizomenon	Fascicles	w [µm] of trichomes	Form of trichomes	Form of akinetes	Dimensions of akinetes [µm]	Terminal cells [µm]	Distribution
flos-aquae	- 2 cm lg	4.5-6.5(8)	± straight	long cylindrical	40-220 x 6-10.8	elongated, hyaline with plasm. string, ± rounded	whole N temp. zone; S American temp. zone
klebahnii	- 3 mm lg	3.2-4.5(5.2)	± straight	long cylindrical	20-54(113) x 5.4-9.3	elongated, ± hyaline with rests of plasma	temperate zones
yezoense	± microscopic, disintegrating bundles	(2)2.7-4	± straight or slightly curved	long cylindrical	31.2-48.9 x 4.7-7.3	long, hyaline, flattened or abruptly rounded	N temperate zone of Eurasia
paraflexuosum	solitary trichomes	3.3-4.8	"flexible"	long cylindrical	44.6-72 x 5.6-7.9	-26.8 long, hyaline, abruptly rounded	Japan
flexuosum	facultatively, only few trichomes	2-4	coiled	cylindrical	20-47(-56) x 3.5-5.7	-42.8 long, hyaline, ± rounded at the apex	N temperate zone of Eurasia
slovenicum	- 2 cm lg	(3)3.7-5.7(7.3)	± straight	short cylindrical	5.5-8.9(22) x 3.3-5.2	elongated, hyaline, rounded at the apex	Slovenia (lake Bled)
platense	solitary or irregular clusters	5.5-6	straight or slightly flexuous	?	?	long, hyaline, conical rounded at the apex	S America, estuary of La Plata; N Argentine
hungaricum	solitary	6.5-7	straight or slightly flexuous	oval to cylindrical	15-24.5 x 4.5-10	elongated, without aerotopes, cylindrical, cut at the apex	Hungary (Kis Balaton), Poland

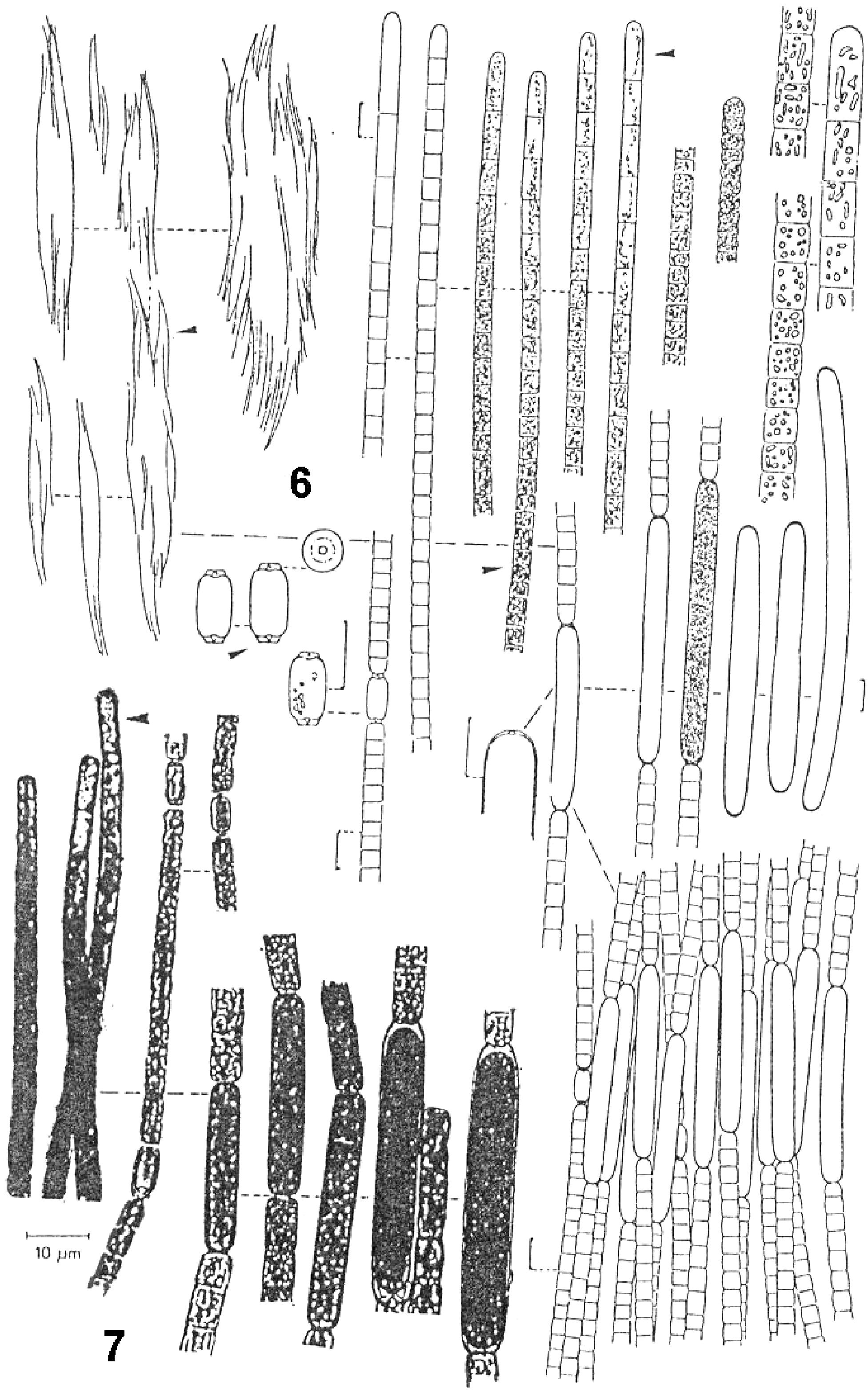


Fig. 6: *Aphanizomenon flos-aquae.* – After KOMÁREK (1958).
Fig. 7: *Aphanizomenon klebahnii.* – After KOMÁREK et KOVÁČIK (1989).

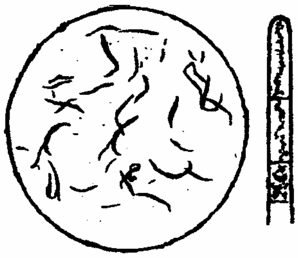
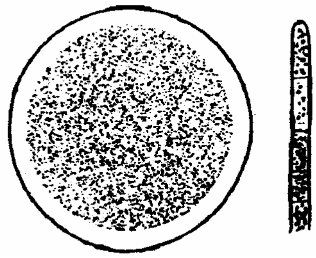
Aphanizomenon	***flos-aqaue***	***klebahnii***
length of colonies trichome width	(2)5-10(20) mm 4.5-6.5(8) µm	0.1-2.0 mm 3.2-4.5(5.2) µm
chlorophyl-a/DW absorbance ratio 480/664 nm (pigment extract) DW/biomass (average)	6-8 µg.mg^{-1} >1.2 0.231 $mg.mm^{-3}$	8-12 µg.mg^{-1} 1.0-1.2 0.291 $mg.mm^{-3}$
transparency zooplankton	> 1 m large *Daphnia*-species	< 0.5 m - small species *Copepoda, Rotatoria*, *Cladocera*
terminal cells size and shape of colonies		

Fig. 8: Comparison of characteristics of *Aphanizomenon flos-aquae* and *Aphanizomenon klebahnii*. – After PECHAR et KALINA (in prep.).

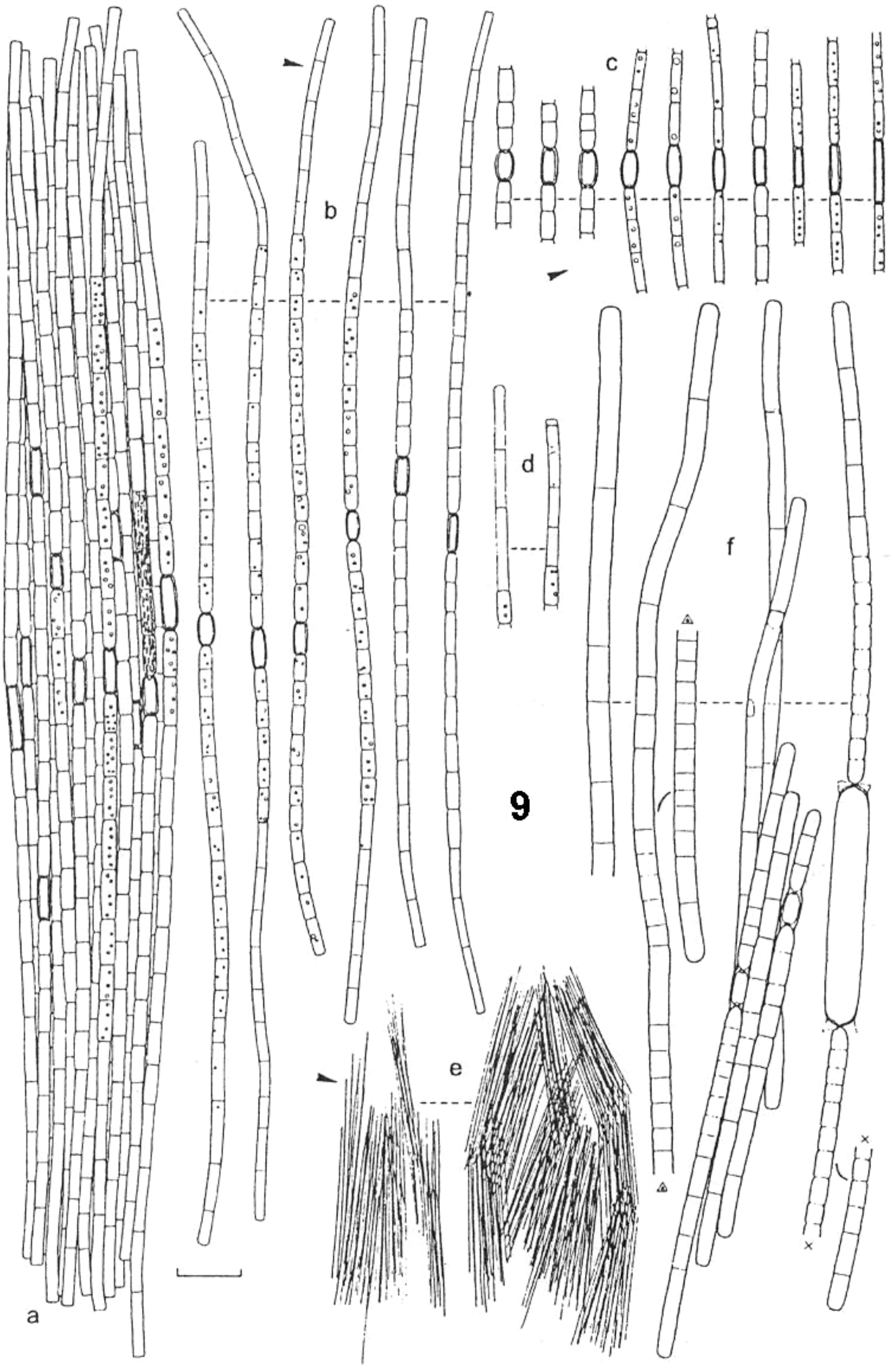


Fig. 9: *Aphanizomenon yezoense.* – After HINDÁK et MOUSTAKA (1988) – a-e; and M. WATANABE (1991) – f.

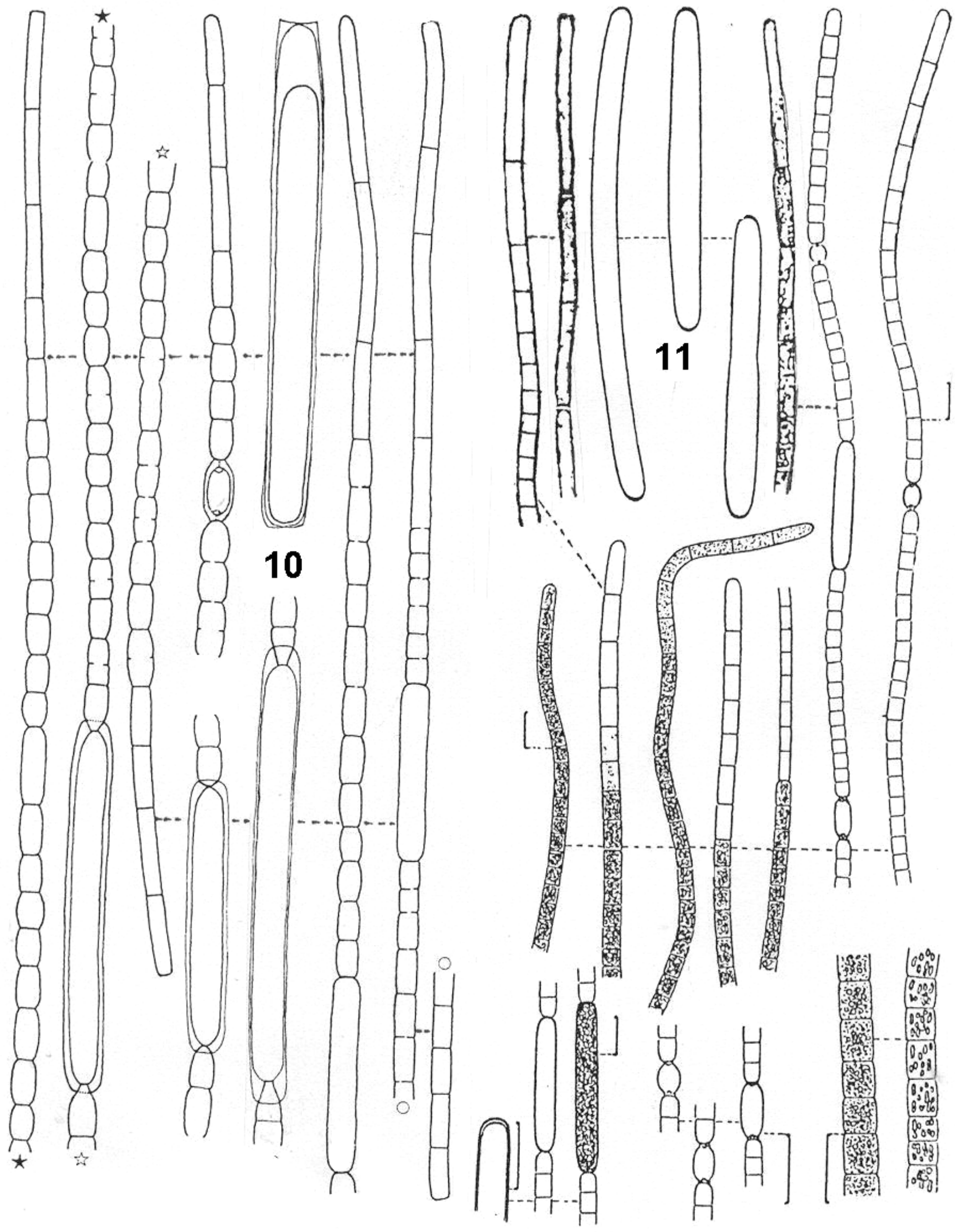


Fig. 10: *Aphanizomenon paraflexuosum*. – After M.WATANABE (1991).
Fig. 11: *Aphanizomenon flexuosum*. – After KOMÁREK et KOVÁČIK (1989).

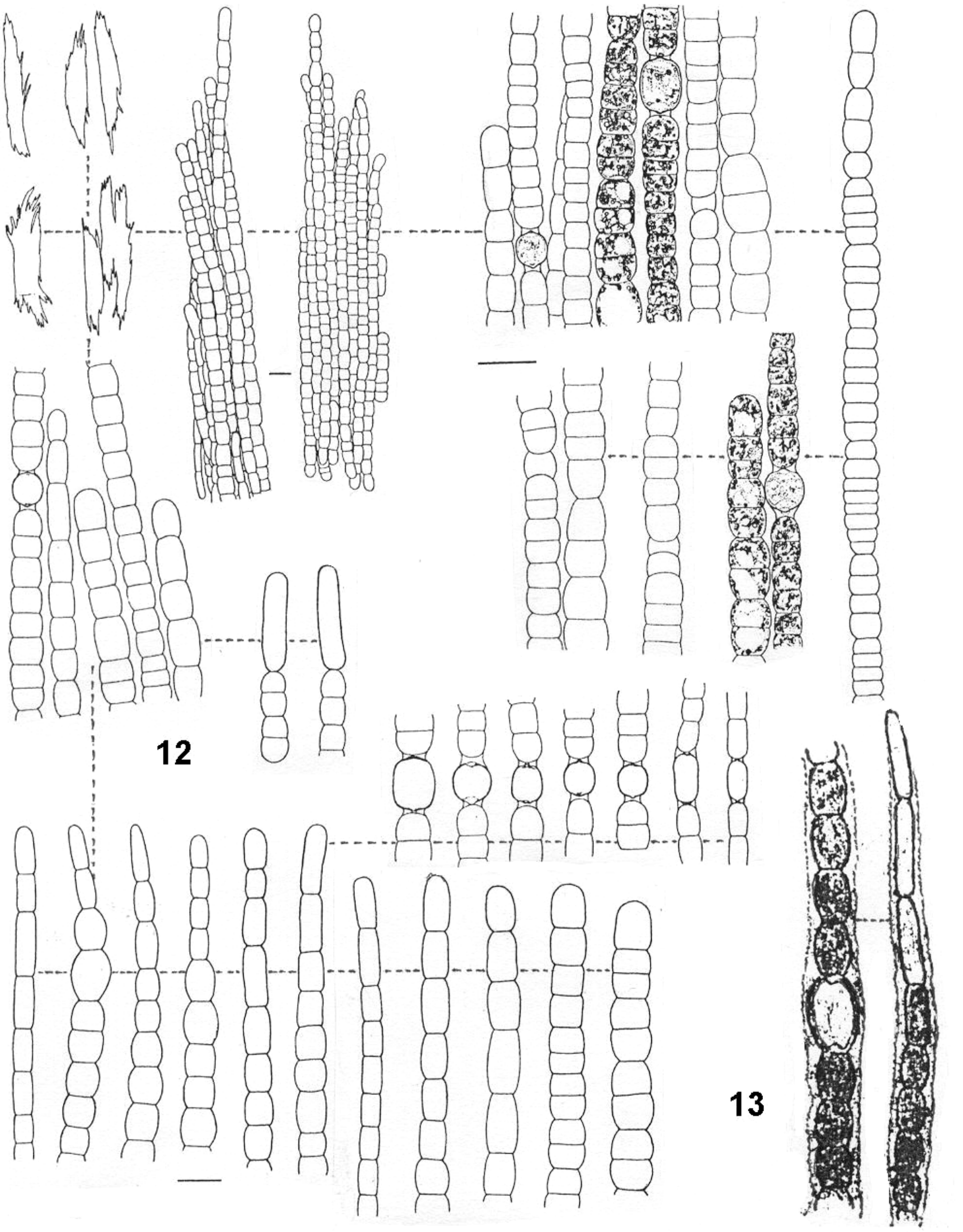


Fig. 12: *Aphanizomenon slovenicum*. – After REKAR et HINDÁK (2002).
Fig. 13: *Aphanizomenon platense.* – After SECKT (1922).

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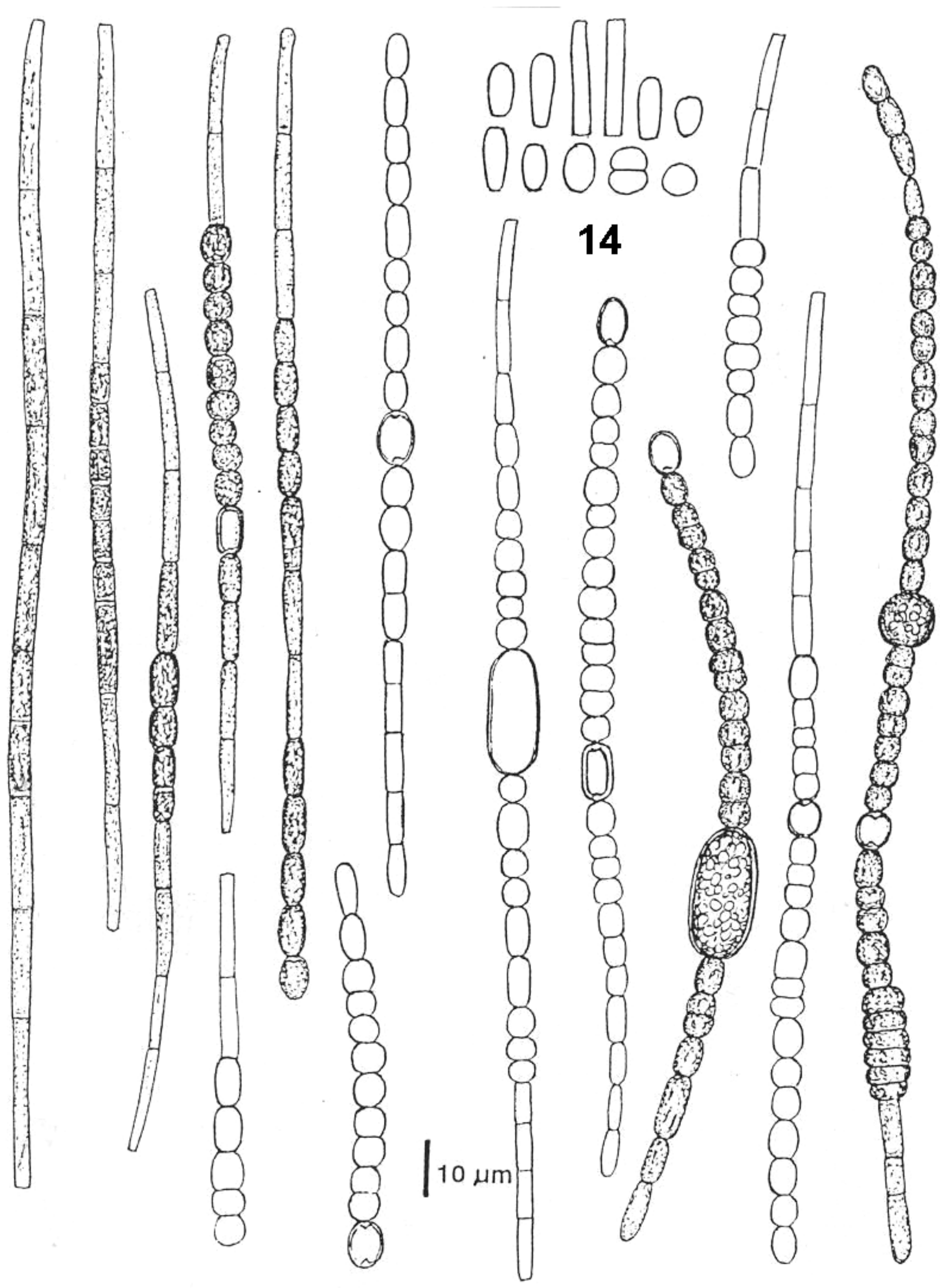

Fig. 14: *Aphanizomenon hungaricum.* – After KOMÁRKOVÁ-LEGNEROVÁ et MÁTYÁS (1995).

(**B**) Morphotype of "***Aphanizomenon gracile***" (Fig. 15)

Trichomes free-floating (mainly freshwater planktic, rarely metaphytic), straight or slightly arcuated, solitary, without sheaths, sometimes with very fine, diffluent, indistinct slime, usually constricted at cross-walls, in developed trichomes always slightly or distinctly narrowed towards ends. Cells cylindrical to barrel-shaped, along the whole length of a trichome of the same morphology, obligatory with gas vesicles, terminal cells maximally 2x longer than wide; the apical cells rounded, conical or drop-like (lanceolate). Heterocytes only interkalar, cylindrical or barrel-shaped, 2 or more on the trichome. Akinetes interkalar, cylindrical, oval or almost rounded (typical shape for different species), solitary or rarely in twos, distant or aside of heterocytes, probably arising by fusion of few neighbouring cells; in one trichome 1 or few akinetes. Trichomes have metameric structure.

Maybe still heterogeneous group. According to morphology, the following selected *Aphanizomenon* or *Anabaena*-morphospecies can belong to this cluster:

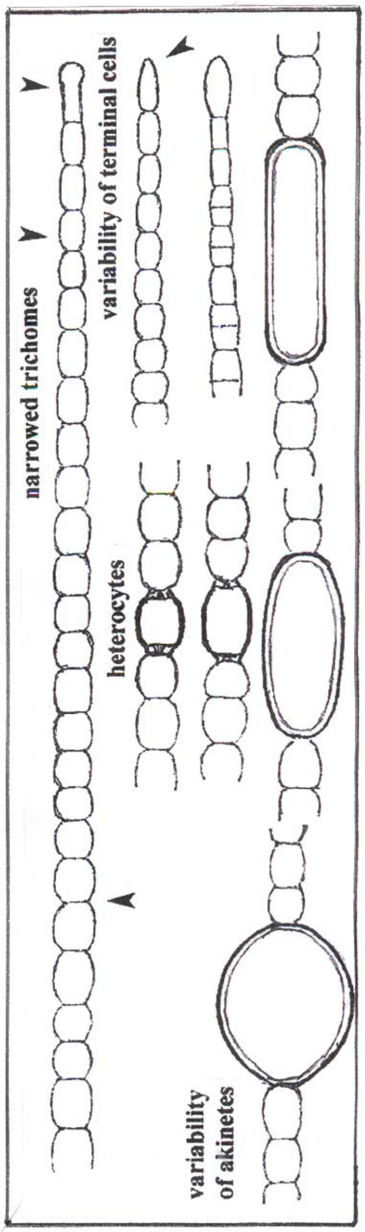

Fig.15: After RAJANIEMI et al.

- ***Aphanizomenon gracile*** (LEMM.) LEMM., Krypt.-Fl. Mark Brandenb. 5: 193, 1910. (Fig. 16) – Temperate zones, planktic in reservoirs.
  Syn.: *Aphanizomenon flos-aquae* var. *gracile* LEMM., Forschungsb. Biol. Stat. Plön 6: 204,1898.
- ***Aphanizomenon skujae*** KOM.-LEGN. et CRONB., Algol. Stud. 67: 26, 1992. (Fig. 17) – Sweden, Finland, planktic in lakes.
  Syn.: *Aphanizomenon* cf. *flos-aquae* var. *klebahnii* sensu SKUJA, N. Acta R. Soc. Sci. Upsal., ser. 4, 18 (3): 71, 1956.
- ***Aphanizomenon ovalisporum*** FORTI, Atti Mem. Acad. Agric. Sci. Lett. Arti Comm. Verona, ser. 4, 12: 125, 1911. (Fig. 18) – Greece, Israel, Italy, Turkey, central Asia, Australia (?), planktic in lakes.
- ***Aphanizomenon schindleri*** KLING et al., Canad. J. Fish. Aquat. Sci. 51: 2270, 1994. (Fig. 19) – Canada, planktic in lakes.

- ***Aphanizomenon aphanizomenoides*** (FORTI) HORECKÁ et KOM., Preslia 51: 295, 1979. (Fig. 20) – warmer regions of N. temperate zone, planktic in reservoirs and lakes.
  Syn.: *Anabaena aphanizomenoides* FORTI, Atti Mem. Acad. Agric. Sci. Lett. Arti Comm. Verona, ser. 4, 12: 126, 1912.
- ***Aphanizomenon manguinii*** BOURR. in BOURR. et MANGUIN, Alg. Eau Douce Guadeloupe Dép. 1: 155, 1952. (Fig. 21) – tropical America (Brazil, Cuba, Guadeloupe, S. Mexico), planktic in lakes.
- ***Aphanizomenon chinense*** NEGORO, 1943. (Fig. 22) – China.
- ***Aphanizomenon sphaericum*** KISEL., Tr. Zool. Inst. Ak. Nauk SSSR 16: 573, 1954. (Fig. 23) **-** Kazakhstan, planktic in lakes.
- ***Anabaena hatueyi*** KOM., Preslia 77: 219, 2005. (Fig. 24) – Cuba, planktic in lakes.
- ***Anabaena nodularioides*** GEITL. in GEITL. et RUTTN., Arch. Hydrobiol., Suppl. 14, 1935. (Fig. 25) – Indonesia, planktic in lakes.
- ***Anabaena recta*** GEITL. in GEITL. et RUTTN., Arch. Hydrobiol., Suppl.14: 459, 1935. (Fig. 26) - Probably pantropical.
- ***Anabaena wisconsinensis*** PRESCOTT, Wisconsin Algae, p. 373, 1944. (Fig. 27) – Temperate zone of North America.
- ***Anabaena minderi*** HUB.-PEST., Binnengew. 16/1: 220, 1938. (Fig. 28) – Austria, Switzerland, large Alpine lakes.
- ***Anabaena bergii*** OSTENF., Phytopl. Aral Sea, Sankt Petersburg, p. 142, 1908. (Fig. 29) – Temperate zone of Eurasia, planktic in saline lakes.

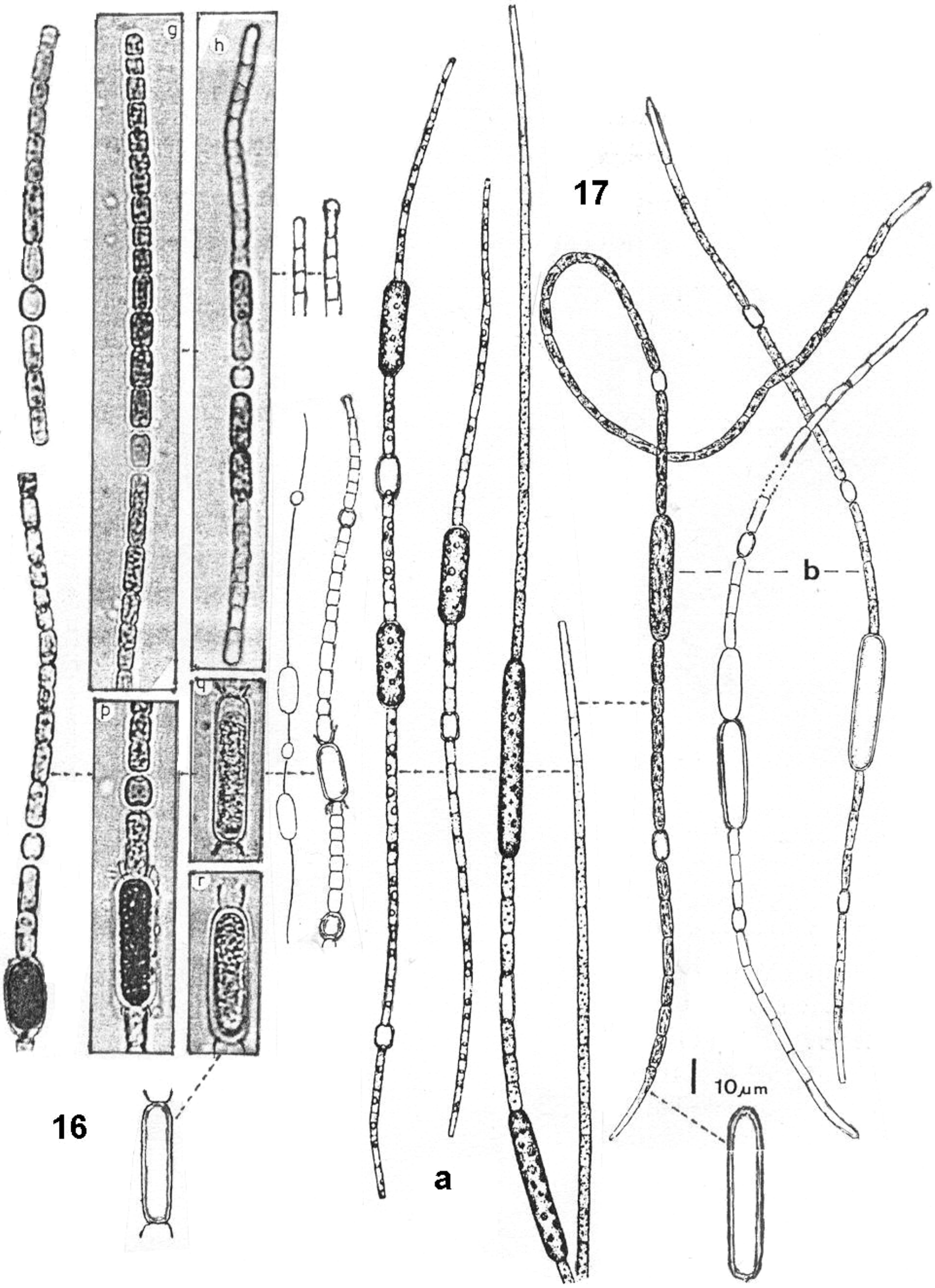

Fig. 16: *Aphanizomenon gracile.* – After KOMÁREK et KOVÁČIK (1989).
Fig. 17: *Aphanizomenon skujae.* – After SKUJA (1956) – a; and KOMÁRKOVÁ-LEGNEROVÁ et CRONBERG (1992).

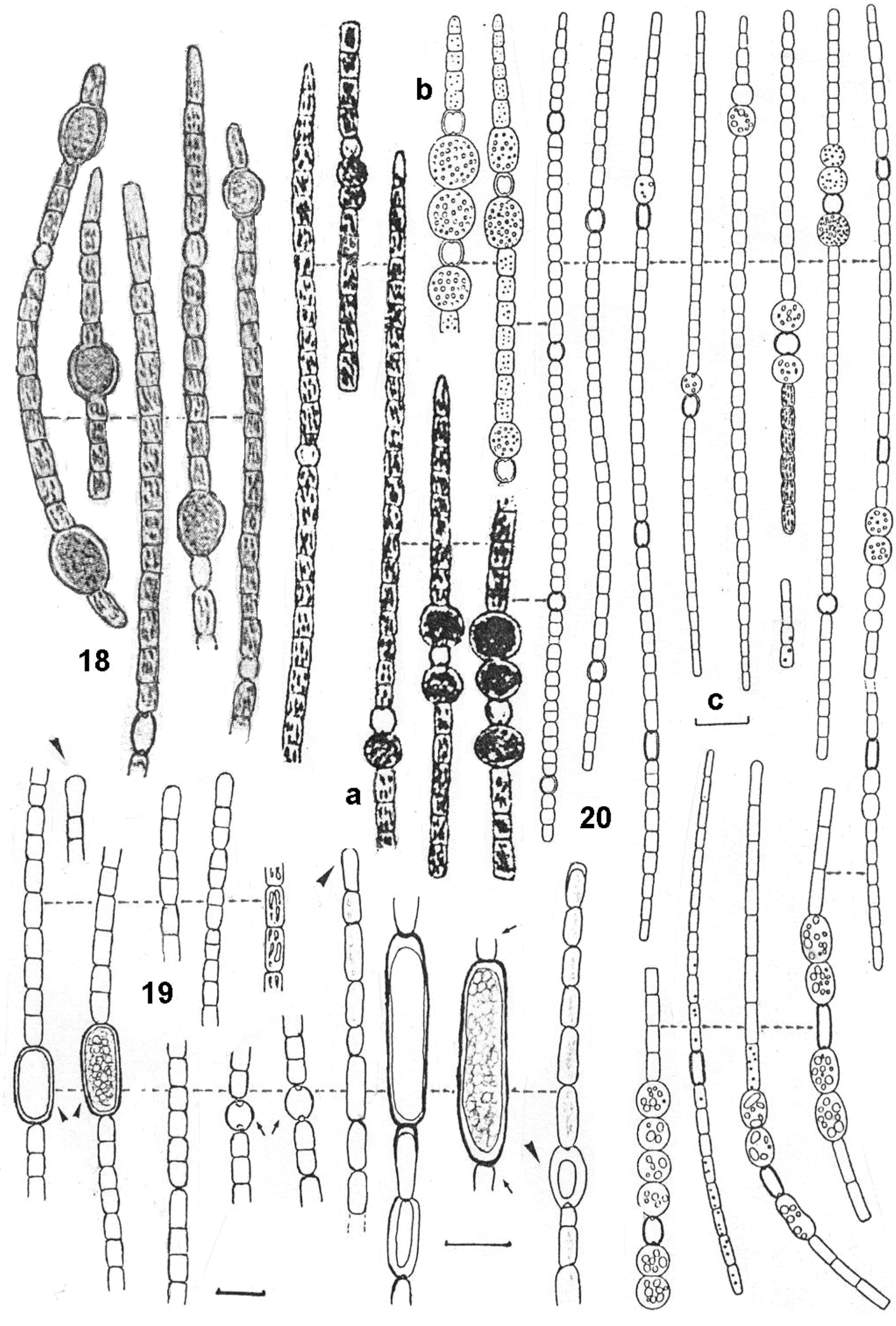

Fig. 18: *Aphanizomenon ovalisporum.* – After FORTI ex GEITLER (1932).
Fig. 19: *Aphanizomenon schindleri.* – After KLING et al. (1994).
Fig. 20: *Aphanizomenon aphanizomenoides.* – After FORTI ex GEITLER (1932) – a; SCHMIDT (1975) - b; and HINDÁK et MOUSTAKA (1988) - c.

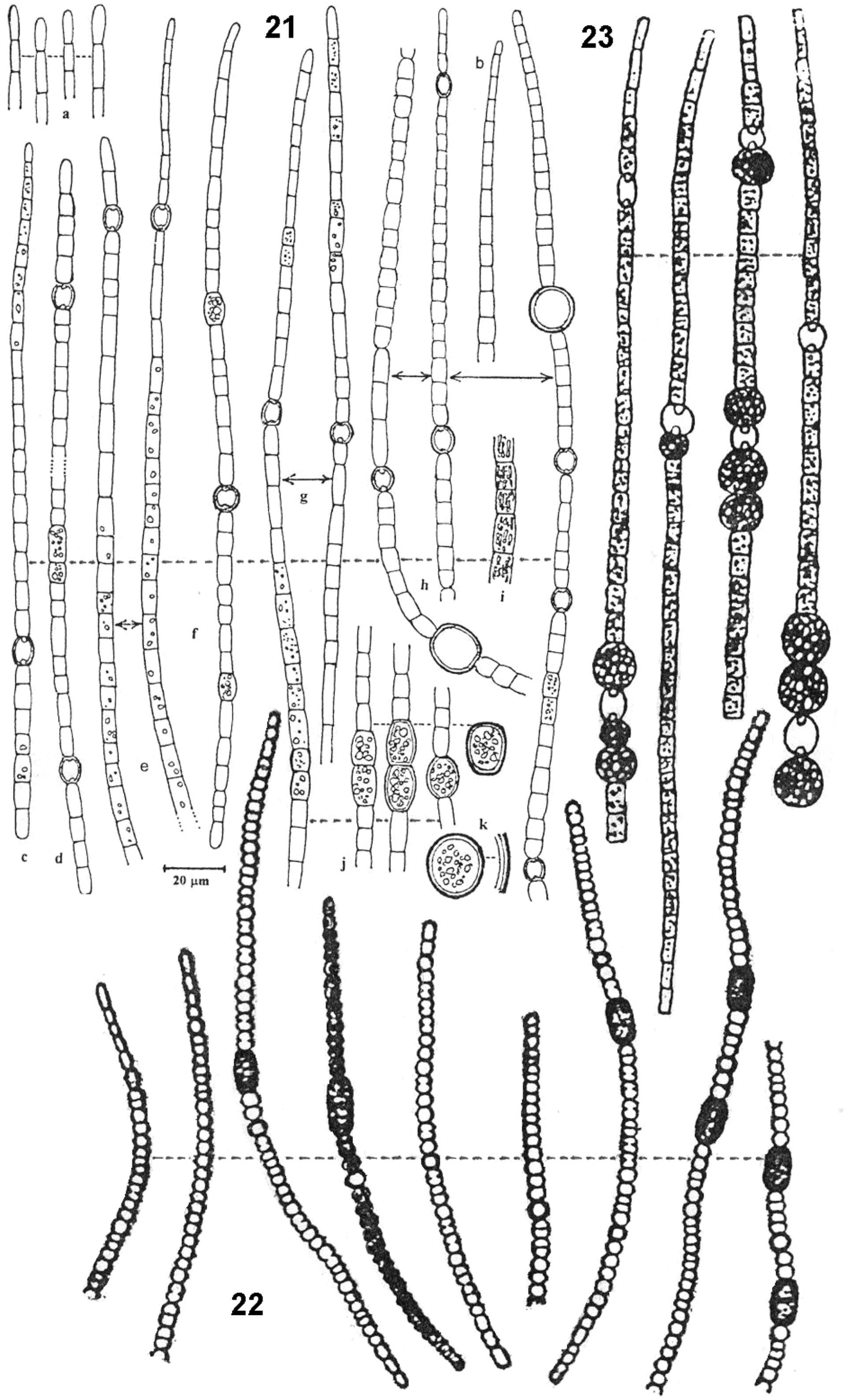

Fig. 21: *Aphanizomenon manguinii.* – After KOMÁREK (1984).
Fig. 22: *Aphanizomenon chinense.* – After NEGORO (1943).
Fig. 23: *Aphanizomenon sphaericum.* – After KISELEV ex KONDRATEVA (1968).

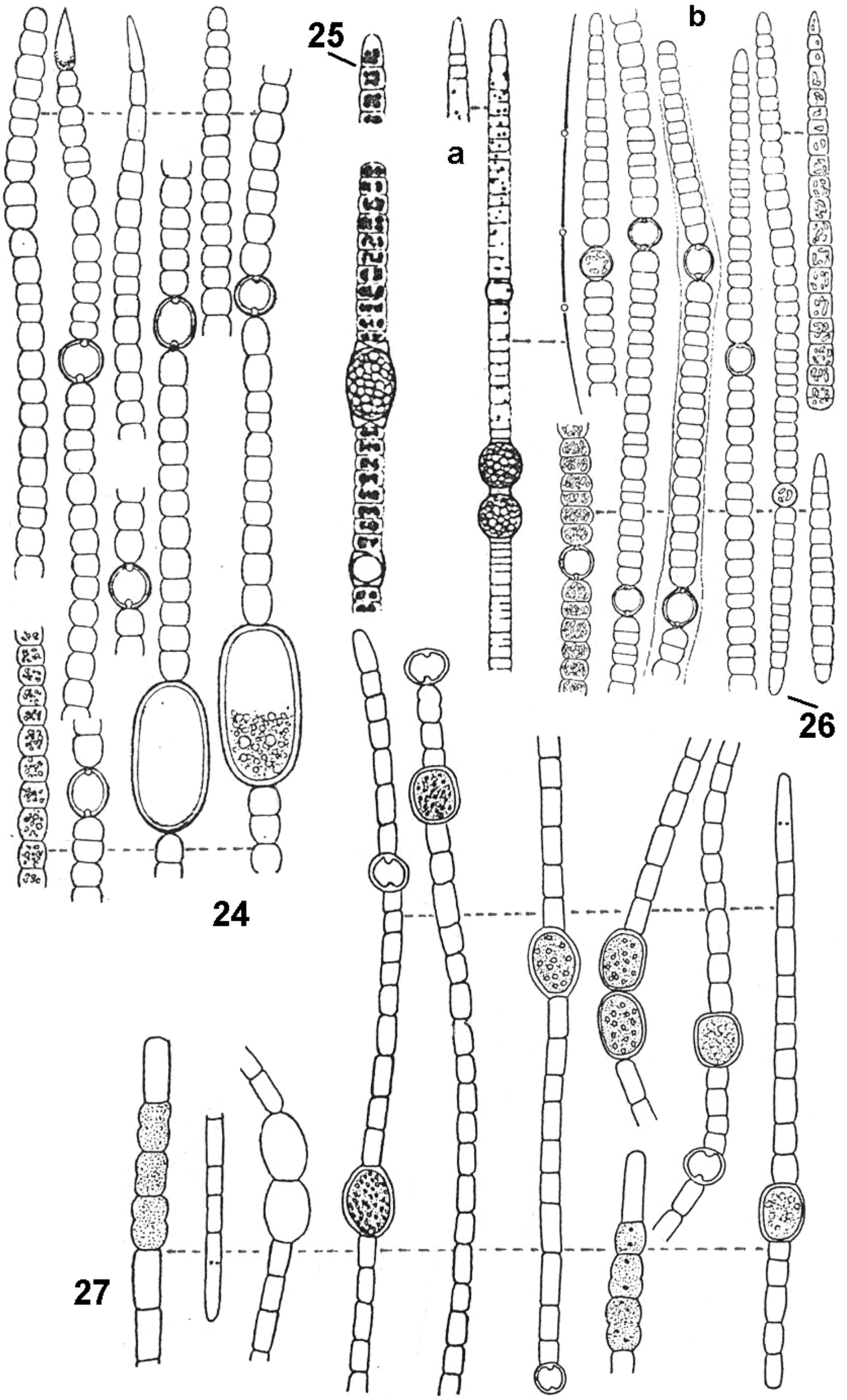

Fig. 24: *Anabaena hatueyi.* – After KOMÁREK (2005).
Fig. 25: *Anabaena nodularioides.*- After GEITLER (1935).
Fig. 26: *Anabaena recta.* – After GEITLER (1935) – a; and KOMÁREK (1984) – b.
Fig. 27: *Anabaena wisconsinensis.* – After PRESCOTT (1944).

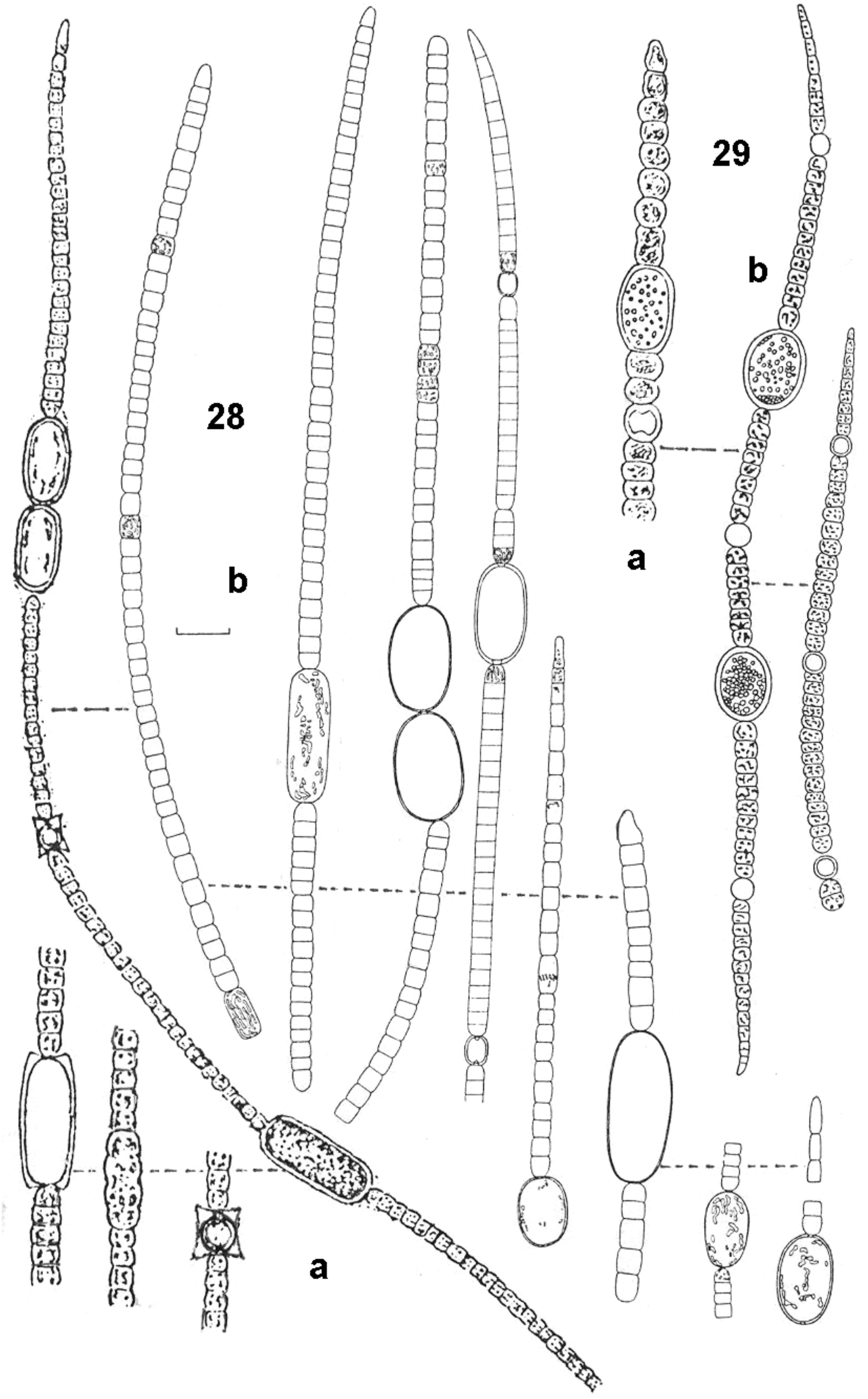

Fig. 28: *Anabaena minderi*.- After HUBER-PESTALOZZI (1938) – a; and HINDÁK (1992) – b.
Fig. 29: *Anabaena bergii.* – After AKSENOVA (1974)) – a; and KISELEV ex KONDRATEVA (1968, sub var. *minor*) - b.

(C) *Cuspidothrix* RAJANIEMI et al., Algolog. Stud. 117, 2005 (Fig. 30)

Trichomes free-floating, usually freshwater, planktic, straight or curved, less frequently coiled, solitary, cylindrical, without sheaths or with very fine and distinct slime, slightly constricted or not constricted at cross-walls, up to 6 µm wide, narrowed towards ends, at the end (developed trichomes) always pointed. Cells cylindrical or with slightly, convex sides (almost barrel-shaped), isodiametric or longer than wide, cell content finely granular and/or with facultatively occurring gas vesicles (solitary aerotopes); apical cells elongated, attenuated, mainly hyaline, attenuated and sharply or bluntly pointed. Heterocytes develop only intercalary, solitary, cylindrical or elliptical. Akinetes intercalary, solitary or rarely in twos, elongated and ± cylindrical (almost spherical in one species), distant from or aside heterocytes, develop probably from several neighbouring cells; in the trichome 1-2 akinetes. Trichomes have subsymmetric structure.

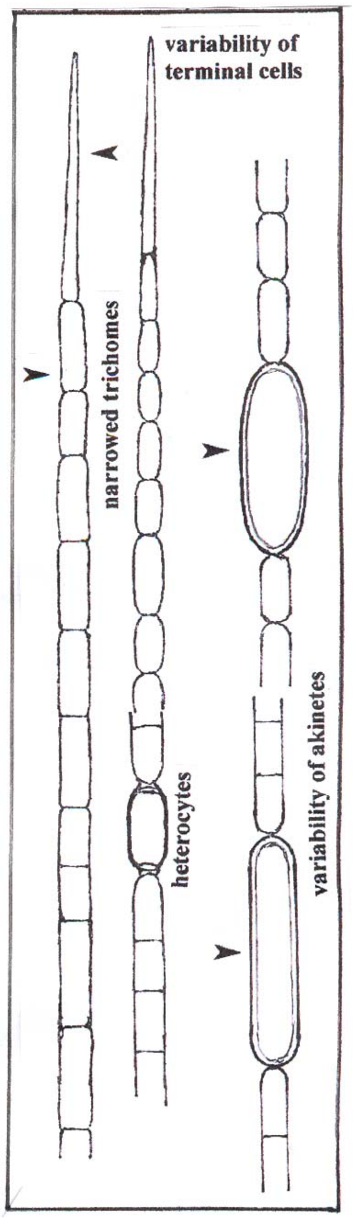

Fig. 30: After RAJANIEMI et al. (2005b)

List of species:

- ***Cuspidothrix issatschenkoi*** (USAČ.) RAJAN. et al., Algolog. Stud. 117, 2005. (Fig. 31)
  Syn.: *Aphanizomenon issatschenkoi* USAČ., Mat. Gidrobiol. Litol. Kasp. Morja, p. 109, 1938.
- ***Cuspidothrix tropicalis*** (HORECKÁ et KOM.) RAJAN. et al., Algolog. Stud. 117, 2005. (Fig. 32)
  Syn.: *Aphanizomenon tropicale* HORECKÁ et KOM., Preslia 51: 297, 1979.
- ***Cuspidothrix elenkinii*** (KISEL.) RAJAN. et al., Algolog. Stud. 117, 2005. (Fig. 33)
  Syn.: *Aphanizomenon elenkinii* KISEL., Not. Syst. Sect. Cryptog. Inst. Bot. 7: 65, 1951.
- ***Cuspidothrix capricorni*** (CRONB. et KOM.) RAJAN. et al., Algolog. Stud. 117, 2005. (Fig. 34)
  Syn.: *Aphanizomenon capricorni* CRONB. et KOM., Nova Hedwigia 78 (1-2): 71, 2004.

- ***Cuspidothrix ussatchevii*** (PROŠK.-LAVR. et MAKAR.) RAJAN. et al., Algolog. Stud. 117, 2005. (Fig. 35)
  Syn.: *Aphanizomenon ussatchevii* PROŠK.-LAVR. et MAKAR., Vodor. Pl. Kasp. Morja, “Nauka”, p. 111, 1968.

Key (main diacritical characters):

Cuspidothrix	**Cells**	**Constr.**	**Apical cells**	**Position of akinetes**	**Form of akinetes**	**Distribution**
issatschenkoi	cylindrical	- or (+)	pointed	distant from HTC	cylindrical	N. temperate zone
tropicalis	cylindrical	-	sharply pointed	aside of HTC	cylindrical to oval	pantropical
elenkinii	cylindrical to barrel-shaped	+	bluntly pointed	distant from HTC	long oval	N. temperate zone - Eurasia
capricorni	cylindrical	(+)	bluntly pointed	aside of HTC	oval	S. Africa, tropical America
ussatchevii	cylindrical	-	bluntly pointed	aside of HTC	widely oval	Caspian Sea

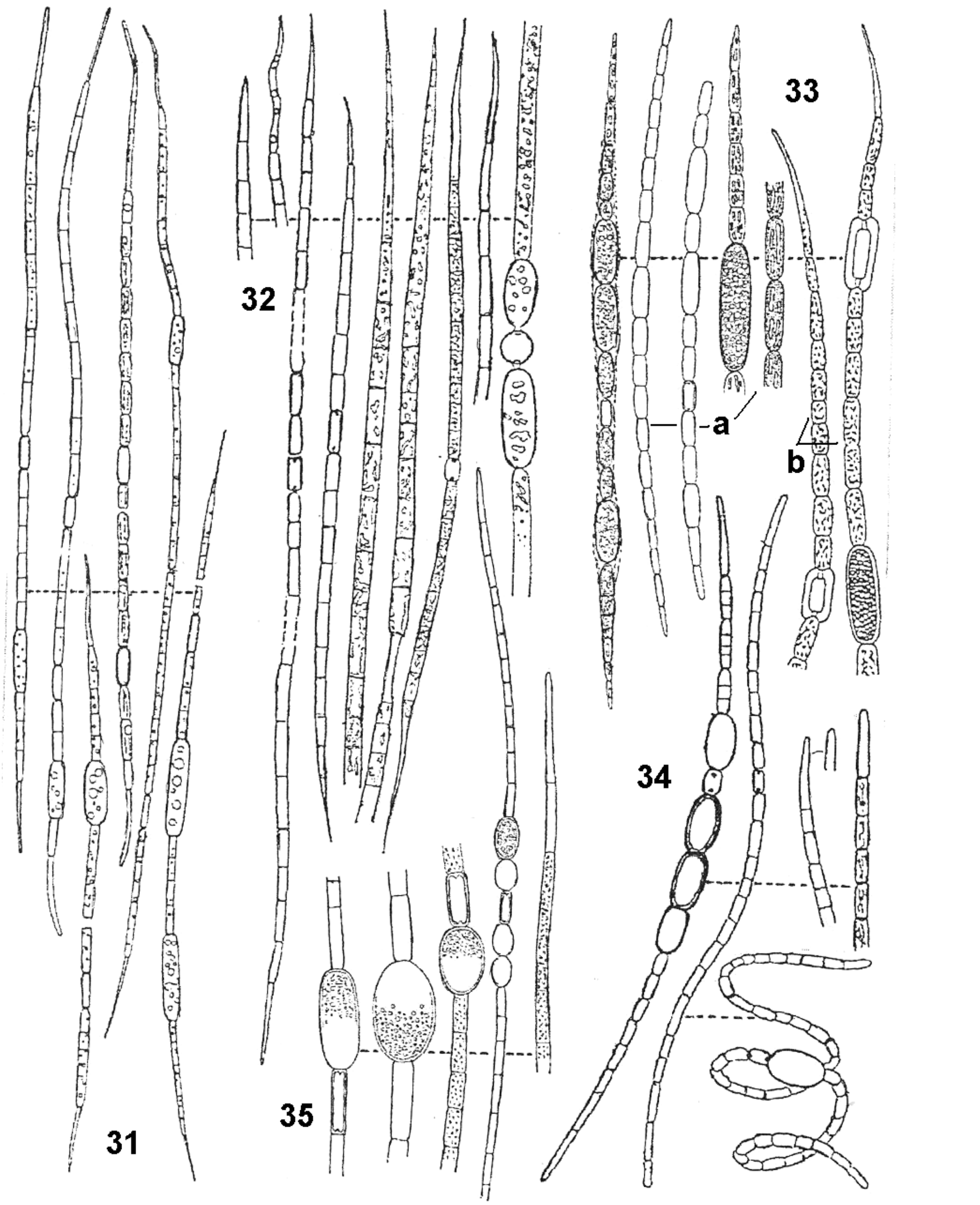

Fig. 31: *Cuspidothrix issatschenkoi.* – After HINDÁK et MOUSTAKA (1988).
Fig. 32: *Cuspidothrix tropicalis.* – After HORECKÁ et KOMÁREK (1979) and CRONBERG et KOMÁREK (2004).
Fig. 33: *Cuspidothrix elenkinii.* – After KOMÁREK (1958) – a; and KISELEV (1951)-b.
Fig. 34: *Cuspidothrix capricorni.* – After CRONBERG et KOMÁREK (2004).
Fig. 35: *Cuspidothrix ussatchevii.* – After PROŠKINA-LAVRENKO et MAKAROVA (1968).

(**D**) Morphotype of "***Aphanizomenon volzii***" (Fig. 36)

Filaments are free-living, solitary or in small clusters, irregularly coiled, mainly metaphytic, rarely secondary planktic. Trichomes with fine, colourless, diffluent, indistinct slime. Trichomes ± coiled, cylindrical, constricted at cross-walls, narrowed to the ends, and sometimes also in the middle. Cells cylindrical, ± isodiametric or rather longer that wide, with blue-green content, usually with scarce granules and facultatively with solitary aerotopes; terminal cells rounded or narrowed and bluntly pointed. Heterocytes always solitary, intercalar, cylindrical, usually wider than vegetative cells, usually two or three in developed trichomes. Akinetes widely oval, developing evidently from several neighbouring cells, large, solitary; several times larger than vegetative cells, always aside of heterocytes; in one trichome develop usually two akinetes, outside from heterocytes in a filament, rarely in twos or at both sides of heterocytes. Trichomes have subsymmetric or almost symmetric structure.

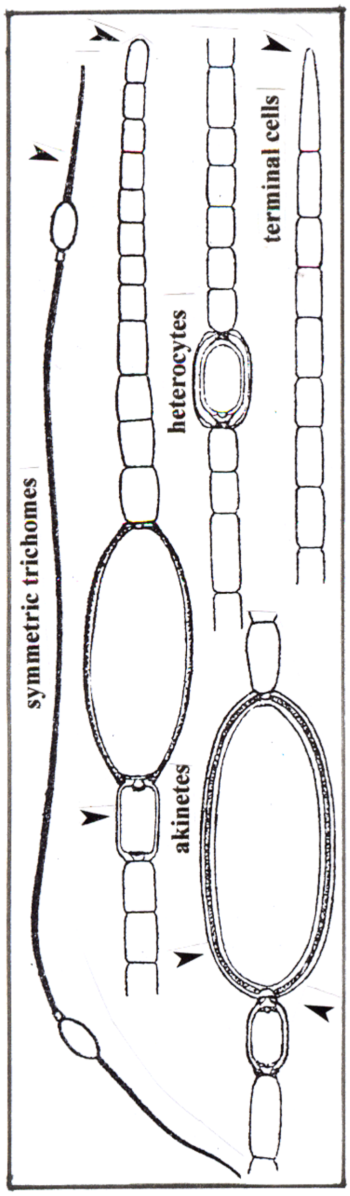

Fig. 36: After KOMÁREK (1984a)

List of species:

- ***Aphanizomenon volzii*** (LEMM.) KOM., Acta Bot. Cubana 18: 9, 1984. (Fig. 37)
  Syn.: *Anabaena volzii* LEMM., Abh. Nat. Ver. Bremen 18: 153, 1906.
  Anabaena volzii f. *recta* KISEL., Žurn. Russ. Bot. Obšč. 16(4): 74, 1931.
- ***Anabaena unispora*** GARDN., Mem. N.Y. Bot. Garden 7: 59, 1927. (Fig. 38)
- ***Anabaena fuellebornii*** SCHMIDLE, Engler´s Bot. Jahrb. 32: 61, 1892. (Fig. 39)

Key (main interspecific diagnostical characters):

"Aphanizomenon /Anabaena"	**Apical cells**	**Cells/width [µm]**	**Akinetes [µm]**	**Surface of akinetes**	**Distribution**
volzii	slightly lenghtened, bluntly pointed	cylindrical 4.5-14 x 4-5.8	(20) 32-48 x (13) 15-21	smooth, (colourless or brownish)	pantropical
unispora	± cylindrical, rounded	cylindrical, 4-10.2 x 4-5.4	(18)20-40(43) x (8)12.5 – 20.5	smooth, (brown)	Cuba, Porto Rico
fuellebornii	slightly narrowed, rounded	barrel-shaped, 3.8-8.2 x 4.8-7.4	25-45 x (14.3)16.5-19(21.6)	granular-dotted, (brownish)	pantropical

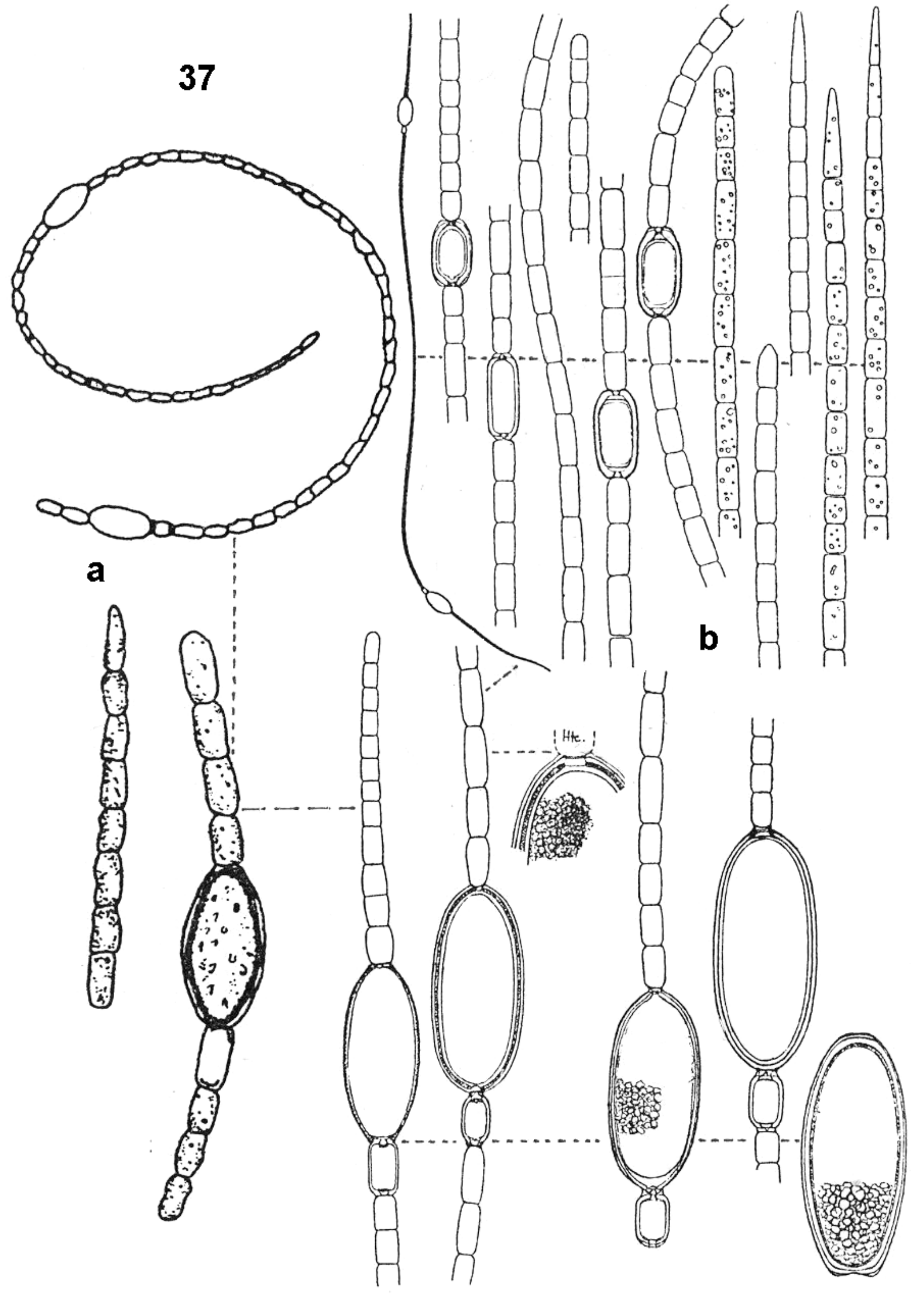

Fig. 37: *Aphanizomenon volzii.* – After LEMMERMANN (1906) – a; and KOMÁREK (1984a) – b.

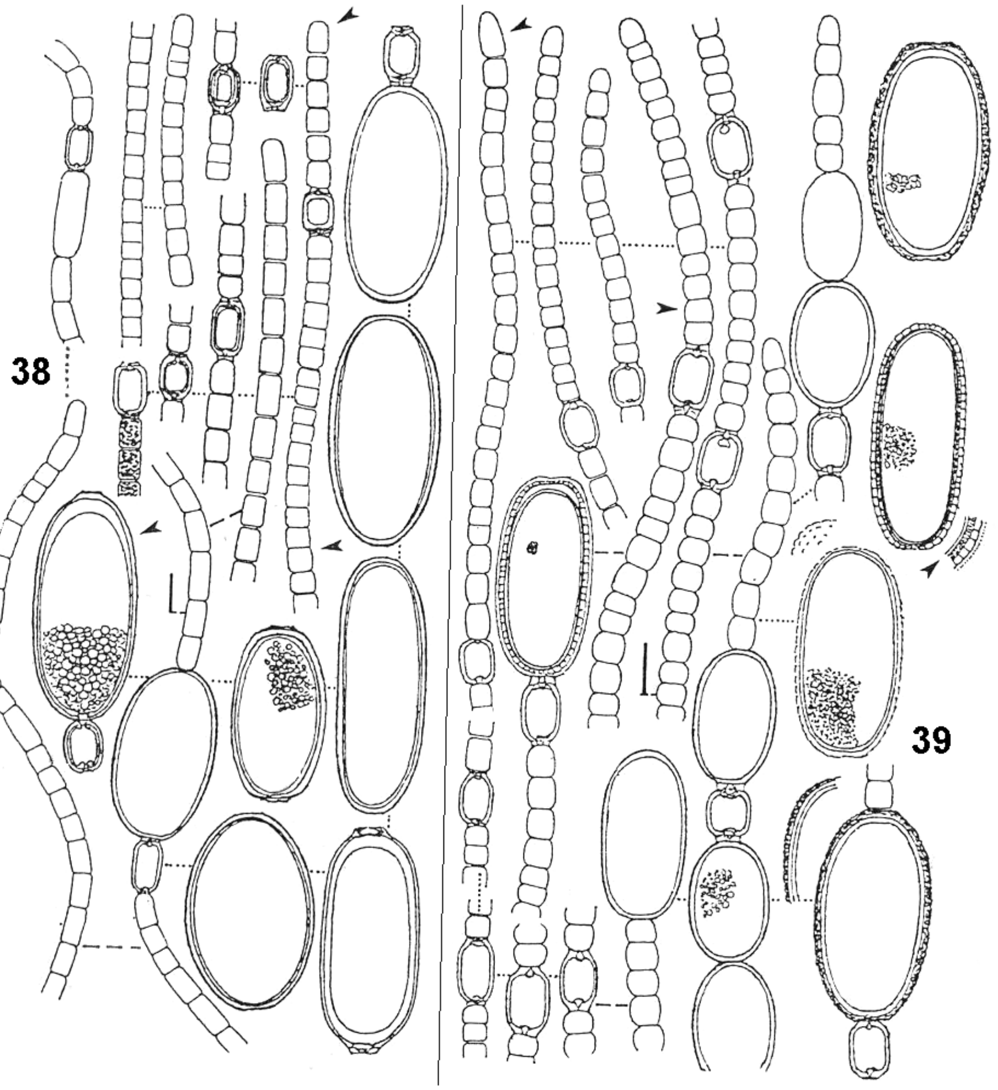

Fig. 38: *Anabaena unispora.* – After GARDNER (1927) and KOMÁREK (2005).
Fig. 39: *Anabaena fuellebornii.* – After KOMÁREK (2005).

Acknowledgement

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