

Planktic morphospecies of the cyanobacterial genus *Anabaena* = subg. *Dolichospermum* – 2. part: straight types

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Abstract: The planktic species of the traditional cyanobacterial genus *Anabaena* represent a special generic entity, different genetically as well as morphologically from the typical (benthic) part of the genus *Anabaena*, based on the type species *Anabaena oscillarioides* BORNET ex BORNET et FLAHAULT. The group of planktic species should be classified in a special subg. *Dolichospermum* THWAITES ex WITTRICK et NORDSTEDT 1889 with the type species *Anabaena flos-aquae* [LYNGBYE] BRÉBISSON ex BORNET et FLAHAULT 1888, which should be transferred to the generic level. The subgenus *Dolichospermum* contains species of two morphological types, with coiled and straight trichomes. Populations of both these types are recognisable in nature without difficulties, but this very marked difference is variable and in disagreement with molecular results; it is particularly transient under culture conditions. It cannot be used therefore to the classification on higher than specific levels (with reservation). In spite of it, we have included the review of species with coiled trichomes in the first part of this list from practical reasons (KOMÁREK & ZAPOMĚLOVÁ 2007). In this second article are included the morphospecies occurring in nature mainly in straight trichomes. The detailed taxonomy of all these types should be solved in future, but our list should be a starting morphological review of this work.

Key words: Cyanobacteria, *Anabaena*, *Dolichospermum*, taxonomy, identification, morphology, variability, morphospecies, phytoplankton, straight trichomes

Introduction

This is a second part of the review of typical planktic *Anabaena* species from the subg. *Dolichospermum* THWAITES ex WITTRICK et NORDSTEDT 1889, which are characterised in natural populations mainly by more or less straight trichomes. The first part, containing the morphospecies with coiled trichomes, has been published in the previous article (KOMÁREK & ZAPOMĚLOVÁ 2007). The important introductory informations are included in this first part. We should like to repeat only, that all the planktic *Anabaena* (*Dolichospermum*) species are very variable. The taxonomy of this whole group is not yet solved definitely, particularly on the species level. The variability in cultures is especially wide and majority of the described morphospecies are not delimited satisfactorily.

Only species, which belong from the generic and morphological view clearly into the planktic cyanobacterial cluster supported, e.g. by the molecular studies of ITEMAN et al. (2002),

GUGGER et al. (2002), RAJANIEMI et al. (2005a,b), WILLAME et al. (2006) and others, and species, the morphology of which indicates the close similarity with these sequenced strains are included in elaboration. All the types are eliminated, which have been recently transferred in other genera (*Aphanizomenon* sensu stricto, *Cuspidothrix*), or have been eliminated genetically from this group. It concerns particularly the group of about 20 “*Anabaena/Aphanizomenon*” species, which grow in \pm straight trichomes with narrowed ends, but they have some morphological characters resembling the genus *Aphanizomenon*. Several of such species were really described under this generic name (e.g., *Aphanizomenon ovalisporum*, *Aph. manguiinii*), but also under *Anabaena* (e.g. *An. bergii*, *An. aphanizomenoides* and several others). Also the groups of species related to *Anabaena volzii* with subsymmetric trichomes, and to *Anabaena elliptica* with narrow, cylindrical trichomes and long cells are eliminated. They both are phenotypically substantially different from the other planktic

Anabaena-types, they were not sequenced among other *Dolichospermum* species and represent probably special generic units.

The importance of cultivation for morphological studies was mentioned in the previous article (KOMÁREK & ZAPOMĚLOVÁ 2007). In the present article we summarise main morphological changes commonly occurring during the cultivation of “straight” species. The features characterising the particular morphospecies are described in detail.

Under culture conditions, modifications of cell size and shape can be particularly observed. Some of these changes are certainly caused by long-term cultivation and “artificial” conditions in culture. Cell shapes are often deformed after a long cultivation and do not correspond exactly to morphology in nature. These morphological changes can be irreversible and cannot be used for estimation of morphological variability.

On the other hand, short-term cultivation can be regarded as a useful tool for study the effect of various growth conditions on morphological variability. Various morphological changes of cyanobacterial strains can be observed early after their isolation that fluctuate in ranges common in nature and that are reversible. In the group of planktic *Anabaena* morphotypes (*Dolichospermum*) with straight trichomes, the main morphological modifications occur in vegetative cell sizes and akinete shapes and dimensions.

Results (review of morphospecies with straight trichomes)

1. *Anabaena affinis* LEMMERMANN, Abh. Naturw. Ver. Bremen 14: 261, 1897; (Fig. 1)

Synonyms: *Anabaena catenula* var. *affinis* (LEMMERMANN) GEITLER, Rabenh.'s Krypt.–Fl. 14: 894, 1932.

Shape of vegetative cells: spherical to slightly barrel-shaped

Width of trichomes: (3)4.5–8 μm

Shape of the end cells: spherical, 2–3 end cells sometimes slightly narrowed

Shape of heterocytes: \pm spherical

Shape of akinetes: ellipsoid to oval

Size of akinetes: 11–30 x 9.2–13 μm

Position of akinetes: distant from heterocytes, solitary or (rarely) in pairs

Diacritical features:

- fasciculated colonies!

- little narrowed apical cells

Variability: Characteristic species, which is, however, often misinterpreted with morphotypes growing in solitary trichomes (usually with *A. viguieri*). The correct documentation and description see in KOMÁREK (1958), KONDRATEVA (1968), M. WATANABE (1992) and HINDÁK (2001). The fasciculated colonies and sometimes elongated, narrowed and hyaline end cells indicate the close relations to *Aphanizomenon*. – In cultures, significant differences in trichome width were observed, mainly in dependence to different temperature. Fasciculated colonies can fall into single trichomes under adverse conditions, both in cultures and nature. When single trichomes are isolated, they reform fascicles under optimal culture conditions.

Distribution: Rarely in mesotrophic to eutrophic stagnant waters; in the whole northern temperate zone, but sporadically.

2. *Anabaena arctica* KISELEV, Gosud. Hidrol.

Inst., Issled. Morej SSSR 15: 98, 1932; (Fig. 2)

Shape of vegetative cells: spherical or truncate at poles

Width of trichomes: (7)8–10(12) μm

Shape of the end cells: probably rounded

Shape of heterocytes: spherical or shortly ellipsoid

Shape of akinetes: ovoid or oval–cylindrical

Size of akinetes: 24–41 x 12–20 μm

Position of akinetes: solitary up to 4 in rows, aside of heterocytes or distant from them

Diacritical features:

- shape of cells

- shape of akinetes

- position of akinetes

- dimensions

- variability

Variability: The trichomes are mostly straight or slightly curved, but also coiled filaments were registered. It is described also a wide variability in akinetes (KISELEV 1932, ELENKIN 1938), but the main shape of ripe akinetes is always similar (ovoid to oval–cylindrical). Probably the akinetes arise aside of heterocytes or distant from them. ELENKIN (1938) joined this type to “*Anabaena scheremetievi*”, which is, however, a very hetero-

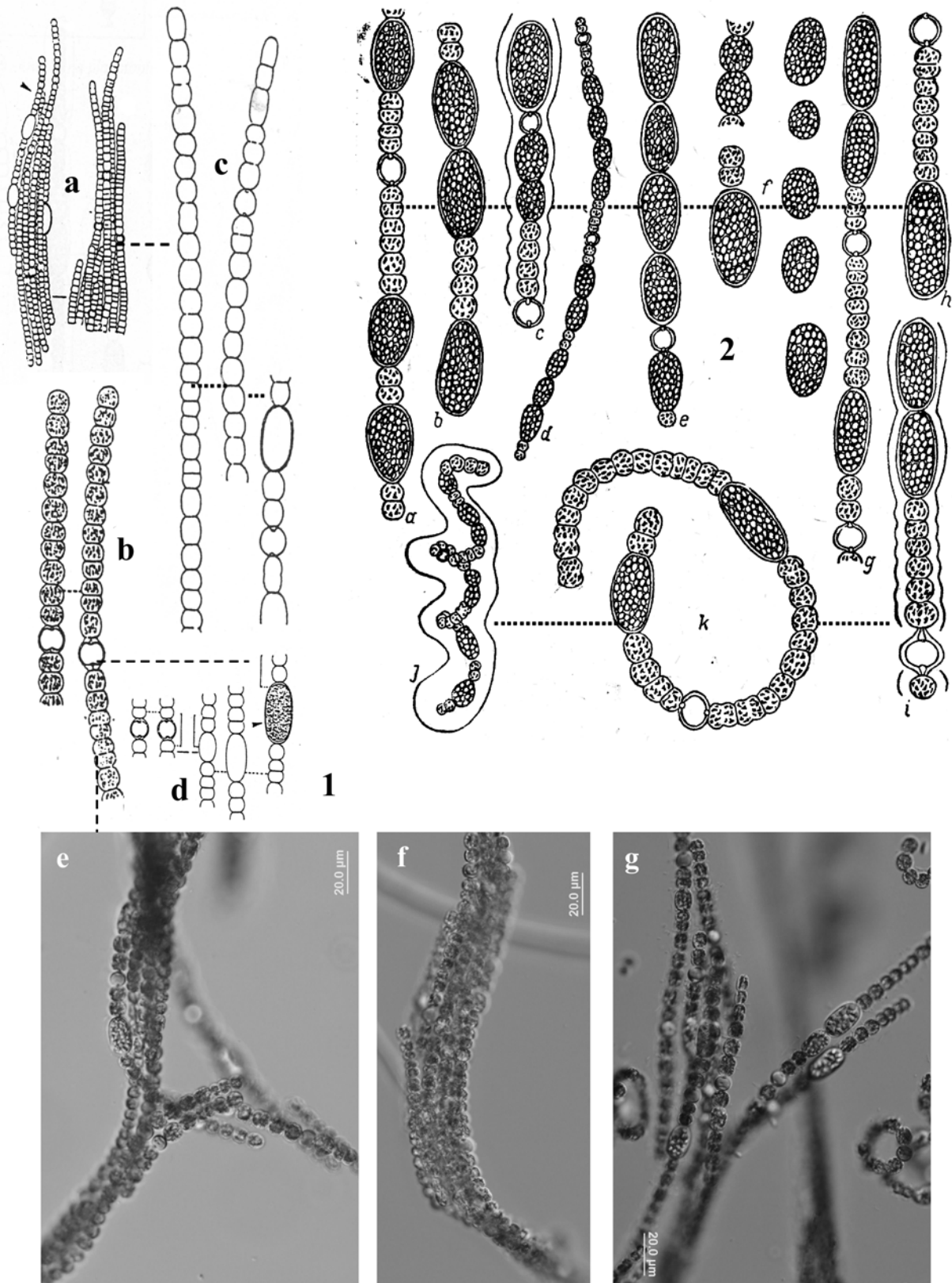


Fig. 1. *A. affinis*: after KOMÁREK (1958) - a-b, d, WATANABE (1992) - c, populations from the Czech Republic - e-g; Fig. 2. *A. arctica*: after KISELEV (1932).

geneous and polymorphic taxon, containing several geno- and morphotypes. Not in cultures.

Distribution: East Siberia, near delta of the river Lena in the freshwater part of Sea Laptevych.

3. *Anabaena bothai* WELSH, Rev. de Biol. 2(3/4): 259–260, 1961; (Fig. 3)

Shape of vegetative cells: ± spherical
 Width of trichomes: 5–6.5 µm
 Shape of the end cells: spherical
 Shape of heterocytes: ± spherical
 Shape of akinetes: wide cylindrical with rounded ends?
 Size of akinetes: ?
 Position of akinetes: from both sides of heterocytes, solitary?

Diacritical features:

- shape of akinetes
- position of akinetes aside of heterocytes
- ecology and distribution

Variability: Not known; incompletely described species.

Distribution: Described from South Africa, not confirmed.

4. *Anabaena citrispora* M. WATANABE, Bull. Nat. Sci. Mus., ser. B, 18(4): 124–126, 1992; (Fig. 4)

Shape of vegetative cells: barrel shaped to ellipsoid, longer than wide (slightly citriform)
 Width of trichomes: (6.8)7.2–9.2(10.1) µm
 Shape of the end cells: ellipsoid, rounded
 Shape of heterocytes: slightly citriform
 Shape of akinetes: widely citriform
 Size of akinetes: (21)24–28(29.5) x 14.9–18.8µm
 Position of akinetes: slightly distant from heterocytes (by 1–3 cells)

Diacritical features:

- shape of cells
- shape and size of akinetes

Variability: Not known. Species close to *A. macrospora* and *A. solitaria*.

Distribution: In lakes, part of a water-bloom; described and known only from Japan (Hokkaido, lake Oonuma).

5. *Anabaena danica* (NYGAARD) KOMÁRKOVÁ–LEGNEROVÁ et ELORANTA, Algolog. Stud. 67: 112, 1992; (Fig. 5)

Synonyms: *Anabaena viguieri* var. *danica* NYGAARD, Kong. Danske Vidensk. Selsk., biol. skr., 7(1): 212, 1949; *Anabaena viguieri* f. *danica* (NYGAARD) KOSINSKAJA, Opred. Presnov. Vodor. SSSR 2: 251, 1953.

Shape of vegetative cells: barrel-shaped, spherical to ellipsoid (usually longer than wide)
 Width of trichomes: 5–7 µm
 Shape of the end cells: rounded
 Shape of heterocytes: ± spherical
 Shape of akinetes: widely oval
 Size of akinetes: 18–19 x 13–17 µm
 Position of akinetes: distant from heterocytes solitary, exceptionally in pairs

Diacritical features:

- shape and size of cells
- shape and size of akinetes
- facultative mucilaginous envelopes around trichomes (5–10 µm wide)

Variability: Not known.

Distribution: Rarely in plankton of eutrophic reservoirs, known mainly from northern regions of Europe, mainly from Baltic region (Denmark, Finland, Sweden).

6. *Anabaena delicatula* LEMMERMANN, Bot. Centralbl. 70: 155, 1898; (Fig. 6)

Synonyms: *Anabaena solitaria* var. *tenuis* SECKT, Bol. Acad. Nac. Cienc. Córdoba (Argentina) 25: 418, 1921.

Shape of vegetative cells: elongated, ±cylindrical to barrel-shaped
 Width of trichomes: ± 3–4.5 µm
 Shape of the end cells: cylindrical and rounded
 Shape of heterocytes: spherical or ellipsoid
 Shape of akinetes: almost cylindrical
 Size of akinetes: 7–19 x 5–8 µm
 Position of akinetes: slightly distant from heterocytes, solitary?

Diacritical features:

- position and form of akinetes
- shape and size of cells

Variability: Not known. Very rarely cited, probably in different concepts. Little known species.

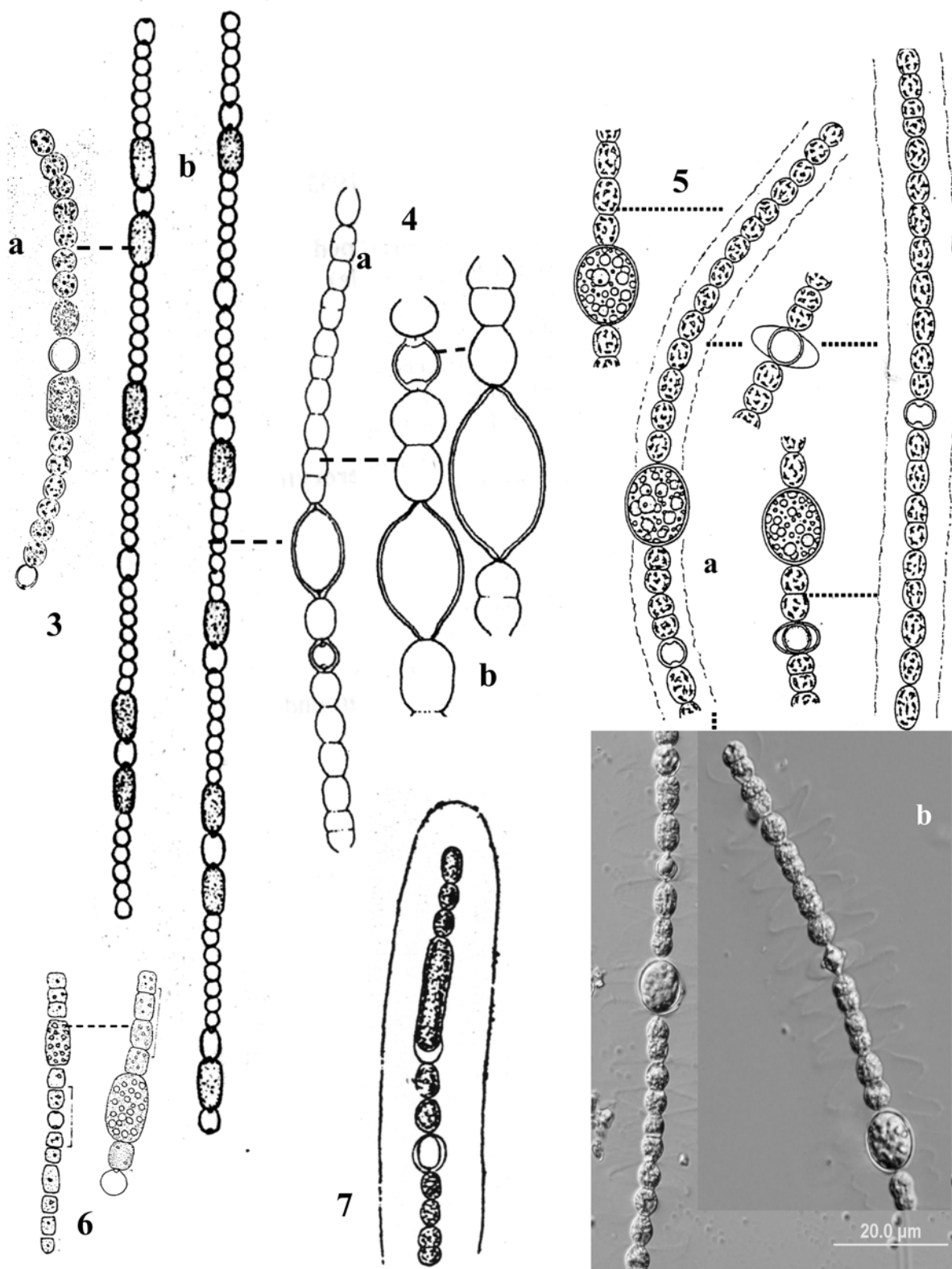


Fig. 3. *A. bothai*: after WELSH (1961); Fig. 4. *A. citrispora*: after WATANABE (1992); Fig. 5. *A. danica*: after NYGAARD (1949) – a, populations from the Czech Republic – b; Fig. 6. *A. delicatula*: after COMPÈRE (1970); Fig. 7. *A. halbfassii*: after BACHMANN from GEITLER (1932).

Distribution: Planktic in stagnant waters. Described from northern Germany, considered as “cosmopolitan”, but very little known. Revision and confirmation of different localities and of the whole species is desirable.

7. *Anabaena halbfassii* BACHMANN, Ber. Dtsch. Bot. Ges. 31: 187, 1913; (Fig. 7)

Shape of vegetative cells: spherical, ellipsoidal to elongated and barrel-shaped
 Width of trichomes: $\pm 3.5 \mu\text{m}$
 Shape of the end cells: rounded
 Shape of heterocytes: \pm elliptical
 Shape of akinetes: cylindrical
 Size of akinetes: $\pm 18 \times 5 \mu\text{m}$
 Position of akinetes: slightly distant from heterocytes

Diacritical features:

- position and shape of akinetes
- shape and size of cells
- mucilaginous envelopes around trichomes

Variability: Not known. Indistinctly described, needs revision. Very similar to *A. delicatula* according to description.

Distribution: Described from lakes in Spain and very rarely cited from temperate zone of Europe.

8. *Anabaena heterospora* NYGAARD, Kong. Danske Vidensk. Selsk., Biol. Skr., 7(1): 195, 1949; (Fig. 8)

Shape of vegetative cells: spherical to barrel-shaped
 Width of trichomes: $4.5\text{--}6 \mu\text{m}$
 Shape of the end cells: spherical
 Shape of heterocytes: spherical, usually wider than trichomes
 Shape of akinetes: variable during development, typically cylindrical in ripe state
 Size of akinetes: $25\text{--}36 \times (5.6)8\text{--}9(10) \mu\text{m}$
 Position of akinetes: slightly distant or aside of heterocytes, solitary or in pairs

Diacritical features:

- shape and development of akinetes
- cell form and cell size

Variability: The great variability exists in form of akinetes (from spherical to cylindrical is described

by NYGAARD 1949). However, the different forms occur mainly during development and the typical form of akinetes is only cylindrical. Akinetes can develop aside of heterocytes or distant from them. Not in cultures.

Distribution: Rarely in plankton of mesotrophic stagnant waters; occurs in temperate zone of Europe, more common in northern Europe.

9. *Anabaena jacutica* KISELEV, Gosud. Hidrol. Inst., Issled. Morej SSSR 15: 100, 1932; (Fig. 9)

Shape of vegetative cells: cylindrical to barrel-shaped, longer than wide
 Width of trichomes: $6\text{--}7 \mu\text{m}$
 Shape of the end cells: probably cylindrical and rounded
 Shape of heterocytes: spherical or cylindrical
 Shape of akinetes: \pm cylindrical with rounded ends
 Size of akinetes: $28\text{--}51 \times 9\text{--}12 \mu\text{m}$
 Position of akinetes: from both sides of heterocytes, solitary or in pairs

Diacritical features:

- position and shape of akinetes
- ecology and distribution
- shape of cells

Variability: Not known, not in cultures.

Distribution: In plankton of brackish waters. Described from estuary of the river Lena (Siberia), needs confirmation.

10. *Anabaena kisseleviana* ELENKIN, Monogr. Alg. Cyanoph., pars spec. 1: 777, 1938; (Fig. 10)

Shape of vegetative cells: shortly barrel-shaped to spherical
 Width of trichomes: $6\text{--}8 \mu\text{m}$
 Shape of the end cells: rounded
 Shape of heterocytes: spherical to oval
 Shape of akinetes: spherical to widely elliptical
 Size of akinetes: $15\text{--}21 \times 14\text{--}18 \mu\text{m}$
 Position of akinetes: aside of both sides of heterocytes, solitary or in pairs

Diacritical features:

- position and shape of akinetes

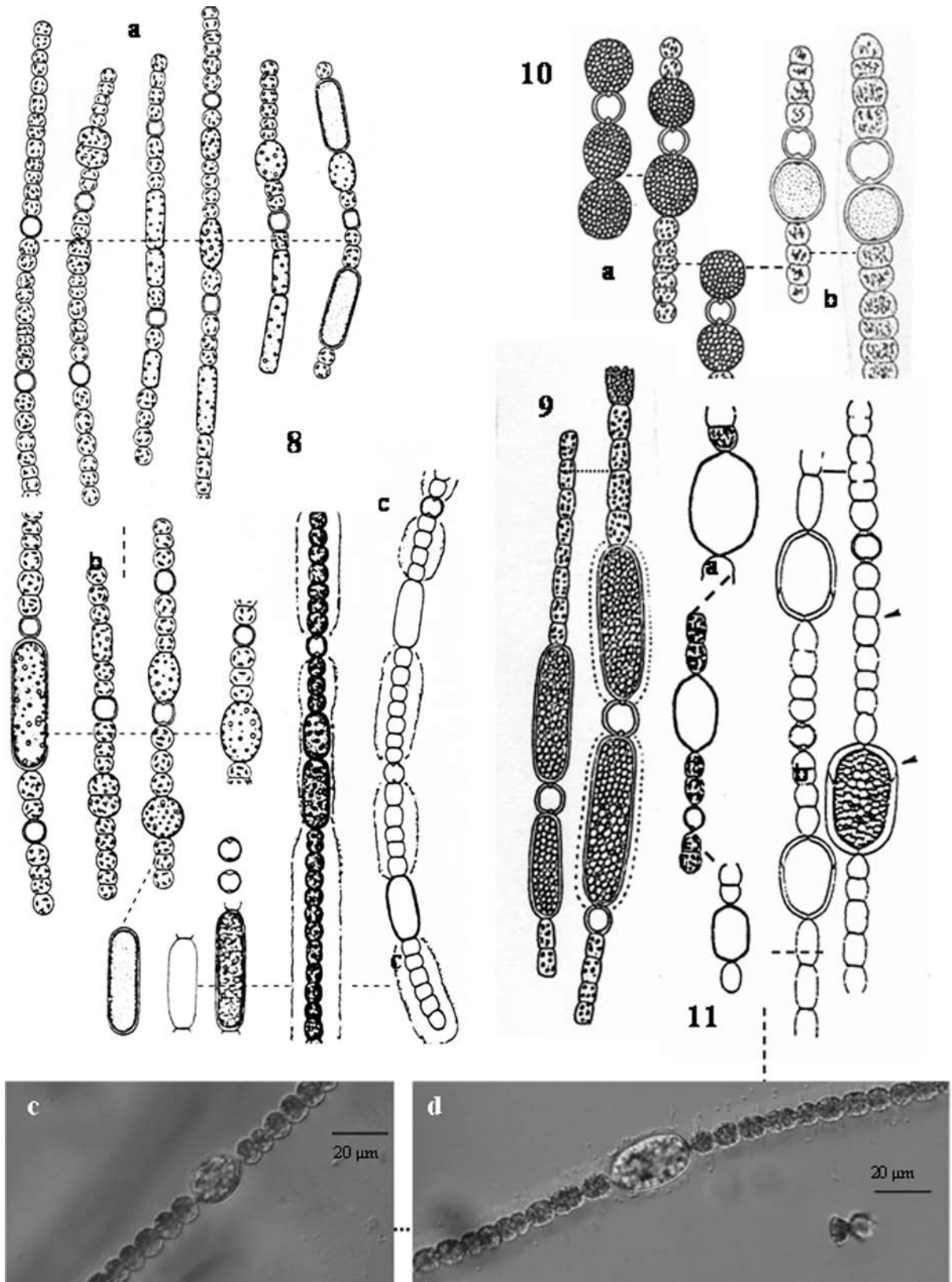


Fig. 8. *A. heterospora*: after NYGAARD (1949) - a-b, KOMÁRKOVÁ-LEGNEROVÁ & ELORANTA (1992) - c; Fig. 9. *A. jacutica*: after KISELEV from STARMACH (1966); Fig. 10. *A. kisseleviana*: after KISELEV from STARMACH (1966) - a, BOURRELLY (1973) - b; Fig. 11. *A. macrospora*: after KLEBAHN ex GEITLER (1932) - a, WATANABE (1992) - b, populations from the Czech Republic - c-d.

- shape of cells

Variability: Not well known. – Two sequences were published in GenBank by Li, Kaya et Watanabe (strains NIES74, TAC34).

Distribution: Known from freshwater and salinic stagnant waters in Siberia. Recorded also from Israel (with smaller dimensions of akinetes), and Japan (strain NIES807).

11. *Anabaena macrospora* KLEBAHN, Flora 80: 269, 1895; (Fig. 11)

Shape of vegetative cells: barrel-shaped, often longer than wide, slightly citriform
 Width of trichomes: 5–8(10) μm
 Shape of the end cells: oval, rounded
 Shape of heterocytes: spherical to slightly oval
 Shape of akinetes: ellipsoid, later (ripe) in outline slightly hexagonal-rounded or in outline almost ovoid, widened in 1/3 of length to the end slightly conical
 Size of akinetes: 17–35 x 11–21 μm
 Position of akinetes: distant from heterocytes (by 1–10 cells), solitary, less frequently two together

Diacritical features:

- shape and variation of vegetative cells
- shape and size of akinetes (with visible seam in the widest place)
- akinetes attain in average 2.4x larger diameter than vegetative cells

Variability: A special form of cells (“citriform”) and akinetes is particularly characteristic for this species. However, just in akinetes exist certain variation (outline, size). Not in cultures.

Distribution: Not common, in slightly eutrophic ponds and lakes, sometimes with higher content of humic matter. In the whole northern temperate zone.

12. *Anabaena maxima* CRONBERG et KOMÁREK, Nova Hedwigia 78(1/2): 77, 2004; (Fig. 12)

Shape of vegetative cells: shortly barrel-shaped
 Width of trichomes: 9–11.4 μm
 Shape of the end cells: spherical to oval, rounded
 Shape of heterocytes: spherical or slightly shorter than wide

Shape of akinetes: cylindrical to oval
 Size of akinetes: 16–43 x 13–20.4 μm
 Position of akinetes: in small distances from heterocytes (with 3–6 vegetative cells), solitary

Diacritical features:

- dimensions
- shape of akinetes with central seam
- terminal hyaline cells

Variability: Not known.

Distribution: In large mesotrophic lakes and reservoirs (forming weak water blooms) of southern Africa (Lake Kariba) and southeastern Brazil (State of São Paulo).

13. *Anabaena nathii* VASISHTA, Res. Bull. (N.S.) Panjab Univ., 11(I–II): 67, 1960; (Fig. 13)

Shape of vegetative cells: shortly barrel-shaped, to spherical
 Width of trichomes: 5.6–7.5(8) μm
 Shape of the end cell: rounded
 Shape of heterocytes: \pm spherical
 Shape of akinetes: oval
 Size of akinetes: 11.2–22.5 x 7.5–11.2
 Position of akinetes: joined to heterocytes from both sides, solitary to 4 in chains

Diacritical features:

- shape of cells
- formation of heterocytes
- shape, position and size of akinetes

Variability: Not known. Heterocytes develop occasionally in pairs (*Anabaenopsis*-like).

Distribution: Described from India (Hoshiarpur), recorded also from Africa (Mali).

14. *Anabaena planctonica* BRUNNTHALER, Sitzungsber. K. Akad. Wiss. Wien, mat.–nat., 103(1): 4, 1903; (Fig. 14)

Synonyms: *Anabaena scheremetievii* ELENKIN, Izd. Imp. S.–Petersburg Bot. Sada 9: 125, 137, 1909, p.p.; *Anabaena limnetica* G.M.SMITH, Bull. Torrey Bot. Club 43(9): 481, 1916; *Anabaena solitaria* f. *solitaria* et f. *planctonica* (BRUNNTHALER) KOMÁREK, Algolog. Studien p. 129, 1958.

Shape of vegetative cells: shortly barrel-shaped
 Width of trichomes: (7.7)8–15 μm

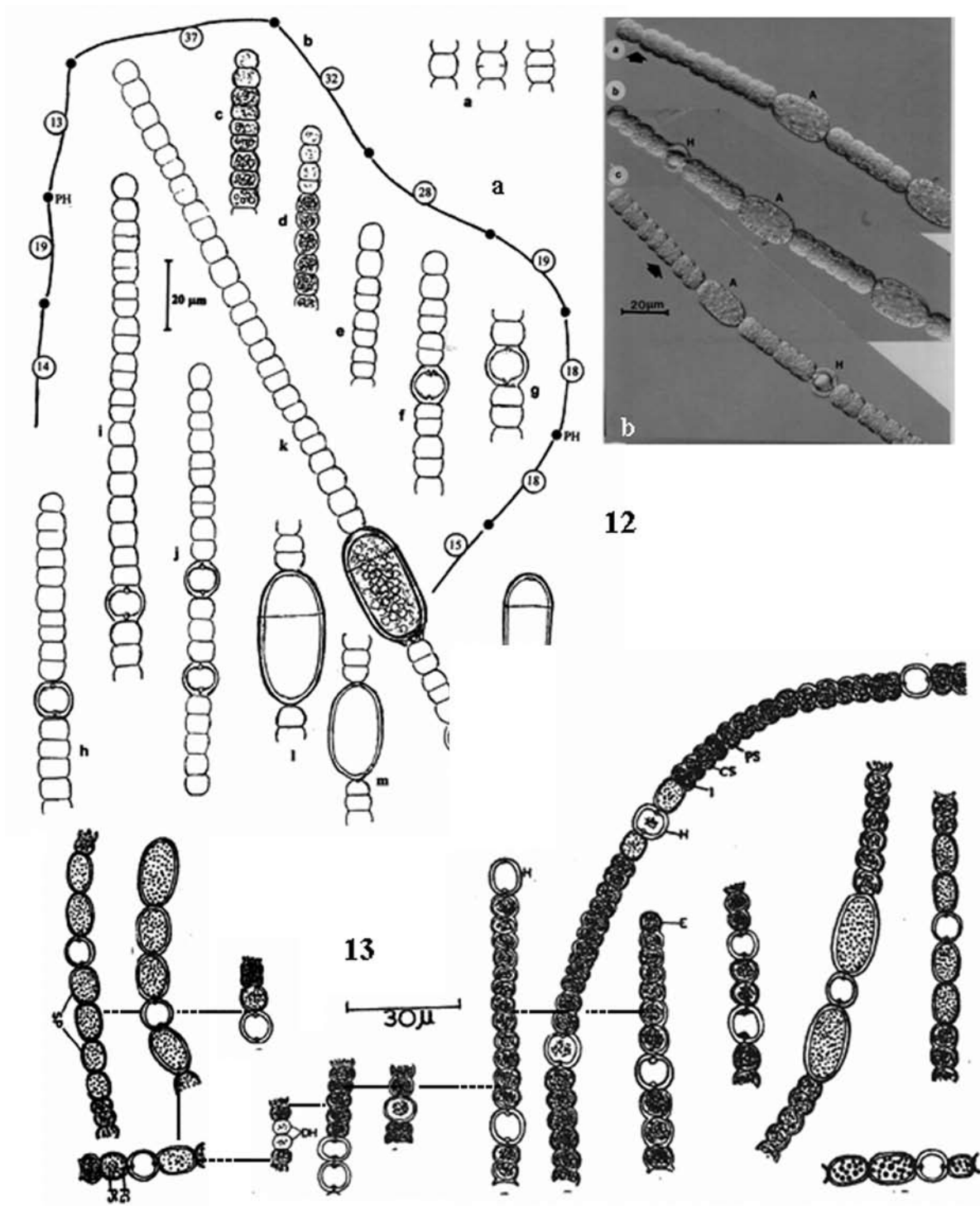


Fig. 12. *A. maxima*: after CRONBERG & KOMÁREK 2004 – a,b; Fig. 13. *A. nathii*: after VASISHTA (1960).

Shape of the end cells: spherical, rounded
 Shape of heterocytes: rounded, nearly spherical, rarely slightly oval
 Shape of akinetes: oval to almost wide cylindrical with rounded ends
 Size of akinetes: 15–37 x 9–21 µm
 Position of akinetes: distant from heterocytes, solitary, less frequently in pairs

Diacritical features:

- shape of cells
- shape, size and position of akinetes

Variability: Variability is not very wide, the size of akinetes changes from cylindrical to oval. Modification of trichome width was observed in cultures, however, it was not very significant. Mucilaginous structures of various shapes can form around vegetative cells, heterocytes and akinetes, both in cultures and nature. According to sequencing related to “large” *Dolichospermum*-types with screw-like trichomes (*A. crassa*, *A. circinalis*, etc.) (RAJANIEMI et al. 2005a,b).

Distribution: Relatively common species in plankton of small and large stagnant water of the whole temperate zone, the occurrence in tropical regions is problematic.

15. *Anabaena smithii* (KOMÁREK) M. WATANABE, Bull. Nat. Sci. Mus., ser. B, 18(4): 131, 1992; (Fig. 15)

Synonyms: *Anabaena planctonica* sensu G.M. SMITH, Phytopl. Inl. Lakes Wisconsin 1: 56, 1920 (sine typo); *Anabaena solitaria* f. *smithii* KOMÁREK, Algolog. Studien p. 129, 1958; *Anabaena scheremetievii* var. *recta* f. *rotundospora* ELENKIN, Izv. Imp. S.-Petersburg. Bot. Sada 9: 126,138, 1909.

Shape of vegetative cells: shortly barrel-shaped
 Width of trichomes: (6.4)8–15 µm
 Shape of the end cells: spherical, rounded
 Shape of heterocytes: ± spherical
 Shape of akinetes: ± spherical
 Size of akinetes: (13.8)15–26(30) µm in diameter
 Position of akinetes: slightly distant from heterocytes, solitary, rarely in pairs

Diacritical features:

- shape of trichomes
- shape of cells
- shape and size of spherical akinetes

Variability: Relatively small variation. The size and shape of akinetes is stable in nature, but the shape of akinetes was pretty variable under culture conditions – from typically spherical to oval, similar to akinetes of *A. planctonica*. After inoculation to fresh culture medium, the strain with prevailing oval akinetes was able to form spherical akinetes again. According to sequencing of 16S rRNA, rpoB and rbcLX genes, *A. smithii* and *A. planctonica* are closely related (RAJANIEMI et al. 2005 b).

Distribution: Common in plankton of mesotrophic to slightly eutrophic stagnant waters; in the whole temperate zone.

16. *Anabaena solitaria* KLEBAHN, Flora 80: 270, 1895; (Fig. 16)

Synonyms: ?*Anabaena lohammari* SKUJA, N. Acta Soc. Sc. Upsal., ser. 4, 16(3): 71, 1956; ?*Anabaena scheremetievii* var. *macrosporoides* TROICKAJA, Bull. Jard. Bot. Petrogr. 21(3): 168, 1922.

Shape of vegetative cells: spherical to oval elongated (citriform!)
 Width of trichomes: 6.5–10(12) µm
 Shape of the end cells: slightly elongated and rounded
 Shape of heterocytes: spherical, sometimes slightly citriform
 Shape of akinetes: long cylindrical
 Size of akinetes: 20–45 x 10–16 µm
 Position of akinetes: slightly distant from heterocytes, usually separated by 1–2(4) vegetative cells

Diacritical features:

- morphology of vegetative cells
- shape of akinetes
- position and shape of akinetes

Variability: The species is often misinterpreted with *A. planctonica*, but the form of vegetative cells (more “citriform”) and position and shape of akinetes are different.

Distribution: In plankton of lakes and larger water bodies, forming diffuse “water-blooms”; in temperate zones, mostly in northern regions, rarely southwards up to region with “mediterranean” climate.

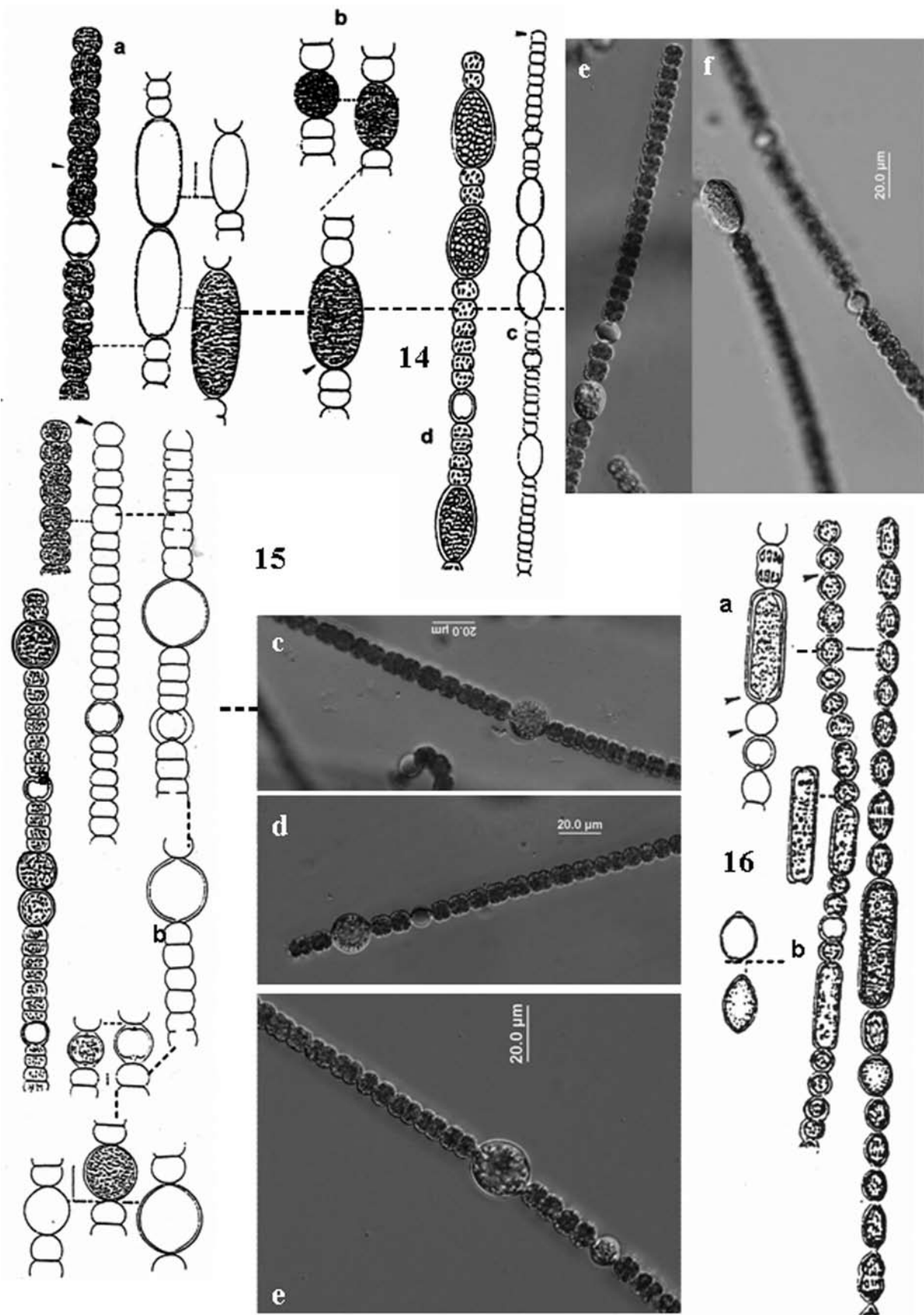


Fig. 14. *A. planctonica*: after KOMÁREK (1958) - a-c, KISELEV ex KONDRATEVA (1968) - d, populations from the Czech Republic - e-f; Fig. 15. *A. smithii*: after KONDRATEVA (1968) - a, KOMÁREK (1958) - b, populations from the Czech Republic - c-e; Fig. 16. *A. solitaria*: after KLEBAHN ex KONDRATEVA (1968) - a, SKUJA ex STARMACH (1966) - b.

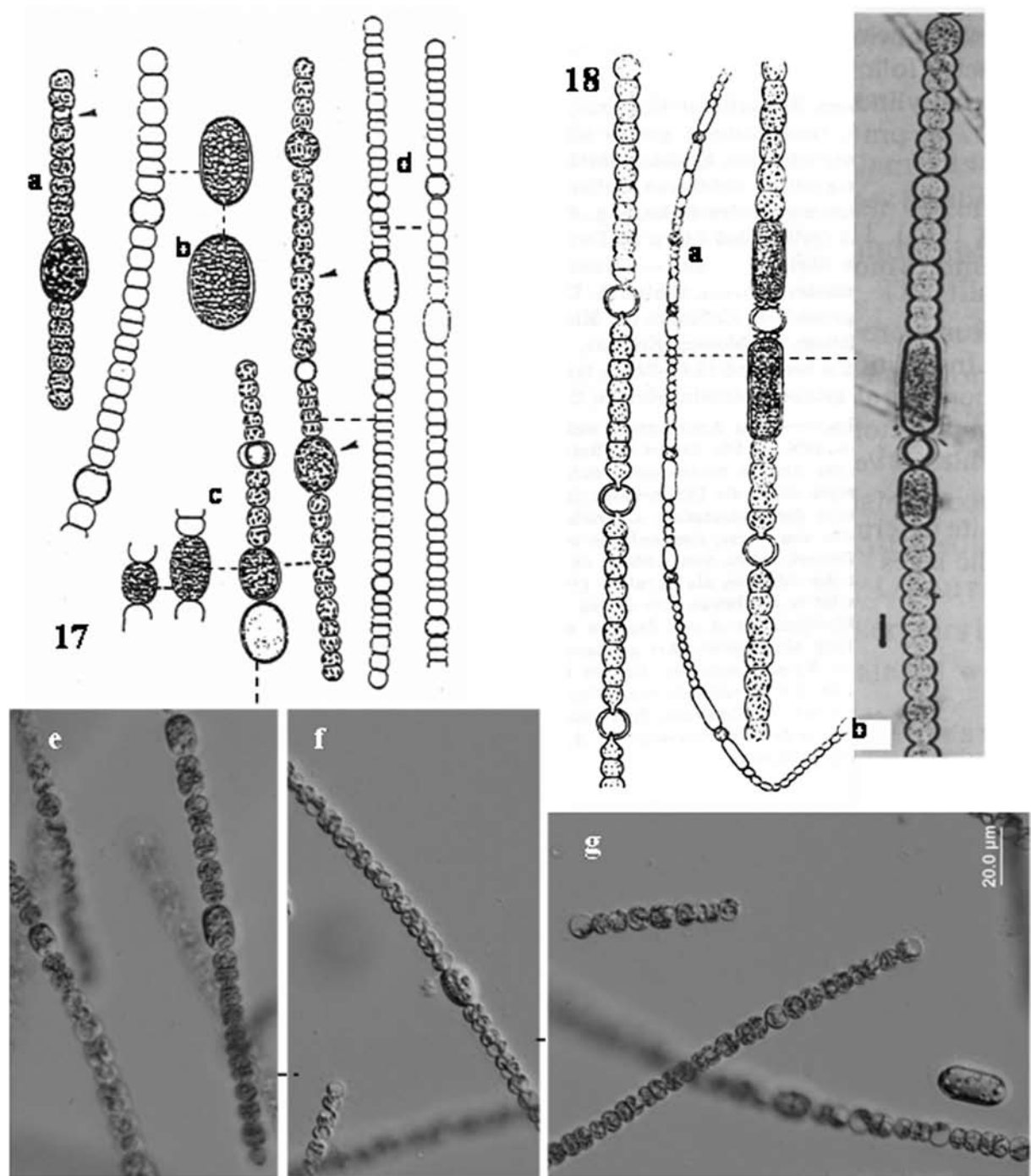


Fig. 17. *A. viguieri*: after DENIS et FRÉMY ex GEITLER (1932) - a, KOMÁREK (1958) - b,d, NYGAARD (1949) - c, populations from the Czech Republic - e-g; Fig. 18. *A. zinserlingii*: after KOSINSKAJA ex HUBER-PESTALOZZI (1938) - a, KOMÁRKOVÁ-LEGNEROVÁ & ELORANTA (1992) - b.

17. *Anabaena viguieri* DENIS et FRÉMY, Bull. Soc. Linn. Normandie, Ser. 7, 6: 122, 1924; (Fig. 17)

Synonyms: *Anabaena affinis* f. *viguieri* (DENIS et FRÉMY) KOMÁREK, Algolog. Studien, p. 124, 1958.

Shape of vegetative cells: spherical to short barrel-shaped, isodiametric or slightly shorter than wide

Width of trichomes: (4.6)5–9(10.2?) μm

Shape of the end cells: spherical

Shape of heterocytes: spherical or short barrel-shaped

Shape of akinetes: ellipsoid to oval

Size of akinetes: (12.8)13.5–30 x (9)11–16 μm

Position of akinetes: distant from heterocytes, solitary, very rare in pairs

Diacritical features:

- solitary trichomes
- width of trichomes
- cell shape

Variability: Variable species, always in solitary trichomes. Changes in trichome width were observed under culture conditions. The intervals of trichome width of smaller *A. viguieri* and larger *A. planctonica* slightly overlap and identification of the morphospecies can be therefore problematic.

Distribution: In plankton of mesotrophic to eutrophic stagnant waters. Common in the whole temperate zones, Europe to central Asia, in North America often recorded as “*A. affinis*” by older authors. Data from tropical regions need confirmation.

18. *Anabaena weneri* BRUNNTHALER, Sitzungsber. K. Akad. Wiss. Wien, mat.–nat., 112(1): 292, 1903

Shape of vegetative cells: \pm spherical

Width of trichomes: \pm 7.2 μm

Shape of the end cells: ? spherical

Shape of heterocytes: spherical

Shape of akinetes: spherical

Size of akinetes: to 12 μm in diameter

Position of akinetes: intercalary, distant from heterocytes

Diacritical features:

- shape, size and position of akinetes

Variability: Not known. The species needs revision.

Distribution: Planktic in lakes. Described and known only from Turkey (Abullonia – Göl).

Documentation to *A. weneri* does not exist (scheme according to description).

19. *Anabaena zinserlingii* KOSINSKAJA, Russ. Arch. Protistol. 8(3/4): 245, 248, 1929; (Fig. 18)

Synonyms: *Anabaena solitaria* f. *zinserlingii* (KOSINSKAJA) ELENKIN, Monogr. Alg. Cyanoph., pars spec. 1: 721, 1938.

Shape of vegetative cells: spherical

Width of trichomes: (4.6)5.7–7(9) μm

Shape of the end cells: spherical or oval and rounded

Shape of heterocytes: spherical

Shape of akinetes: long, cylindrical

Size of akinetes: 13.8–34.5(to 85?) x (6.9)8–13(21?) μm

Position of akinetes: from both sides of akinetes

Diacritical features:

- position and shape of akinetes
- ecology and distribution
- shape of cells

Variability: Not known, not in culture. Cf. with *A. jacutica*.

Distribution: Planktic in slightly eutrophic or dystrophic lakes. Known only from lakes of northern Europe (Russia, Finland, Sweden).

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References

- ELENKIN, A.A. (1938): Monographia algarum cyanophycearum aquidulcium et terrestrium in finibus URSS inventarum. [Sinezelenye vodorosli SSSR.] Pars spec./1. – 984 pp., Izd. AN SSSR, Moskva – Leningrad.
- GUGGER, M., LYRA, C., HENRIKSEN, P., COUTÉ, A., HUMBERT, J.-F. & SIVONEN, K. (2002a): Phylogenetic comparison of the cyanobacterial genera *Anabaena* and *Aphanizomenon*. – Internat. J. Syst.

- Evol. Microbiol. 52: 1–14.
- GUGGER, M., LYRA, C., SUOMINEN, I., TSITKO, I., HUMBERT, J.-F., SALKINOJA-SALONEN, M. & SIVONEN, K. (2002b): Cellular fatty acids as chemotaxonomic markers of the genera *Anabaena*, *Aphanizomenon*, *Microcystis*, *Nostoc* and *Planktothrix* (Cyanobacteria). – *Internat. J. Syst. Evol. Microbiol.* 52: 1007–1015.
- GEITLER, L. (1932): Cyanophyceae. – In: RABENHORST'S Kryptogamenflora von Deutschland, Österreich und Schweiz 14: 1–1196, Akad. Verlagsges., Leipzig.
- HINDÁK, F. (2001): Fotografický atlas mikroskopických siníc. – 128 pp., Veda, Bratislava.
- HUBER-PESTALOZZI, G. (1938): Das Phytoplankton des Süßwassers. Systematik und Biologie I. – In: Die Binnengewässer, 16: 1–342.
- ITEMAN, I., RIPPKA, R., TANDEAU DE MARSAC, N. & HERDMAN, M. (2002): rDNA analyses of planktonic heterocystous cyanobacteria, including members of the genera *Anabaenopsis* and *Cyanospira*. – *Microbiology* 148: 481–496.
- KISELEV, I.A. (1932): Beitrag zur Mikroflora der südöstlicher Teil der Laptev-Meeres. – *Inst. Hydrol.: Explor. Meers URSS Leningrad*, 15: 90, 98–100.
- KOMÁREK, J. (1958): Die taxonomische Revision der planktischen Blaualgen der Tschechoslowakei. – In: *Algologische Studien*, p. 10–206, Academia, Praha.
- KOMÁREK, J. & ZAPOMĚLOVÁ, E. (2007): Planktic morphospecies of the cyanobacterial genus *Anabaena* = subg. *Dolichospermum* – 1. part: coiled types. – *Fottea* 7(1): 1–31.
- KONDRATEVA, N.V. (1968): Sin'ozeleni vodorosti – Cyanophyta. [Blue-green algae – Cyanophyta.] – In: *Vizn. prsnov. vodorost. Ukr.RSR* 1,2: 524 pp. – Vid. "Naukova dumka", Kiev.
- NYGAARD, G. (1949): Hydrobiological studies on some Danish ponds and lakes. II. – *Det Kong. Danske Vidensk. Selskab, Biol. Skrifter* 7(1): 1–294.
- RAJANIEMI, P., HROUZEK, P., KAŠTOVSKÁ, K., WILLAME, R., RANTALA, A., HOFFMANN, L., KOMÁREK, J. & SIVONEN, K. (2005): Phylogenetic and morphological evaluation of the genera *Anabaena*, *Aphanizomenon*, *Trichormus* and *Nostoc* (Nostocales, Cyanobacteria). – *Internat. J. Syst. Ecol. Microbiol.* 55: 11–26.
- RAJANIEMI, P., KOMÁREK, J., HROUZEK, P., WILLAME, R., KAŠTOVSKÁ, K., HOFFMANN, L. & SIVONEN, K. (2005): Taxonomic consequences from the combined molecular and phenotype evaluation of selected *Anabaena* and *Aphanizomenon* strains. – *Arch. Hydrobiol./Algolog. Stud.* 117 (Cyanobacterial Research 6): 371–391.
- SMITH, G.M. (1920): Phytoplankton of the Inland lakes of Wisconsin I. – *Wisc. Geol. Nat. Hist. Surv.* 57, Ser. sci., 12: 1–243.
- VASHISTA, C. (1960): *Anabaena nathi* sp. nov. from Hoshiarpur. – *Res. Bull. (N.S.) Panjab Univ.* 11(I–II): 63–67.
- WATANABE, M. (1992): Studies on planktonic blue-green algae 4. Some *Anabaena* species with straight trichomes in Japan. – *Bull. Nat. Sci. Mus., Ser. B.*, 18: 123–137.
- WILLAME, R., BOUTTE, C., GRUBISIC, S., WILMOTTE, A., KOMÁREK, J. & HOFFMANN, L. (2006): Morphological and molecular characterisation of planktonic cyanobacteria from Belgium and Luxembourg. – *J. Phycol.* 42: 1312–1332.

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