Taxonomic review of the cyanoprokaryotic genera *Planktothrix* and *Planktothricoides*

Taxonomický přehled rodů *Planktothrix* a P*lanktothricoides* (Cyanoprokaryota)

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Abstract

The cyanoprokaryotic/cyanobacterial genera *Planktothrix* and *Planktothricoides* belong to the planktic filamentous phormidiacean types. They are well characterized and delimited by phenotype, ultrastructure, and mainly by genetic criteria (molecular sequencing). However, their intrageneric diversity, which is important for ecological research (eutrophication of water reservoirs, toxicity), is complicated, and the classification on the specific level is difficult. The problematics of species identification is discussed in the present review. - The study was supported by the grants EU "MIDI-CHIP EVK2-1999-00213", and GACR No. "KSK 6005114".

Introduction

The genus *Planktothrix* ANAGNOSTIDIS et KOMÁREK 1988 belongs to the important, water-bloom forming and potentially toxic cyanobacterial genera. It was originally classified into the genus *Oscillatoria*, because it grows in solitary trichomes without sheaths, heterocytes and akinetes. However, there are gas vesicles gathered in aerotopes ("gas vacuoles"; see, e.g., WALSBY et al. 1983), localized irregularly within the whole cell volume. Also, the planktic type of life is specific. Thus, the genus *Planktothrix* was separated from *Oscillatoria* in respect to different ultrastructure, life strategy and phenotypic appearance, and this separation was proved also according to molecular 16S rRNA sequencing (Fig. 1; CASTENHOLZ 2001, GeneBank [NCBI] 2000, RIPPKA & HERDMAN 1992, SUDA et al. 2002). *Planktothrix* represents now a unique and strictly delimited

cluster, well distinguishable also according to morphological characters. SUDA et al. (2002) described later another special genetic entity (with morphologically similar filaments), as a separate genus *Planktothricoides* (Fig. 2).

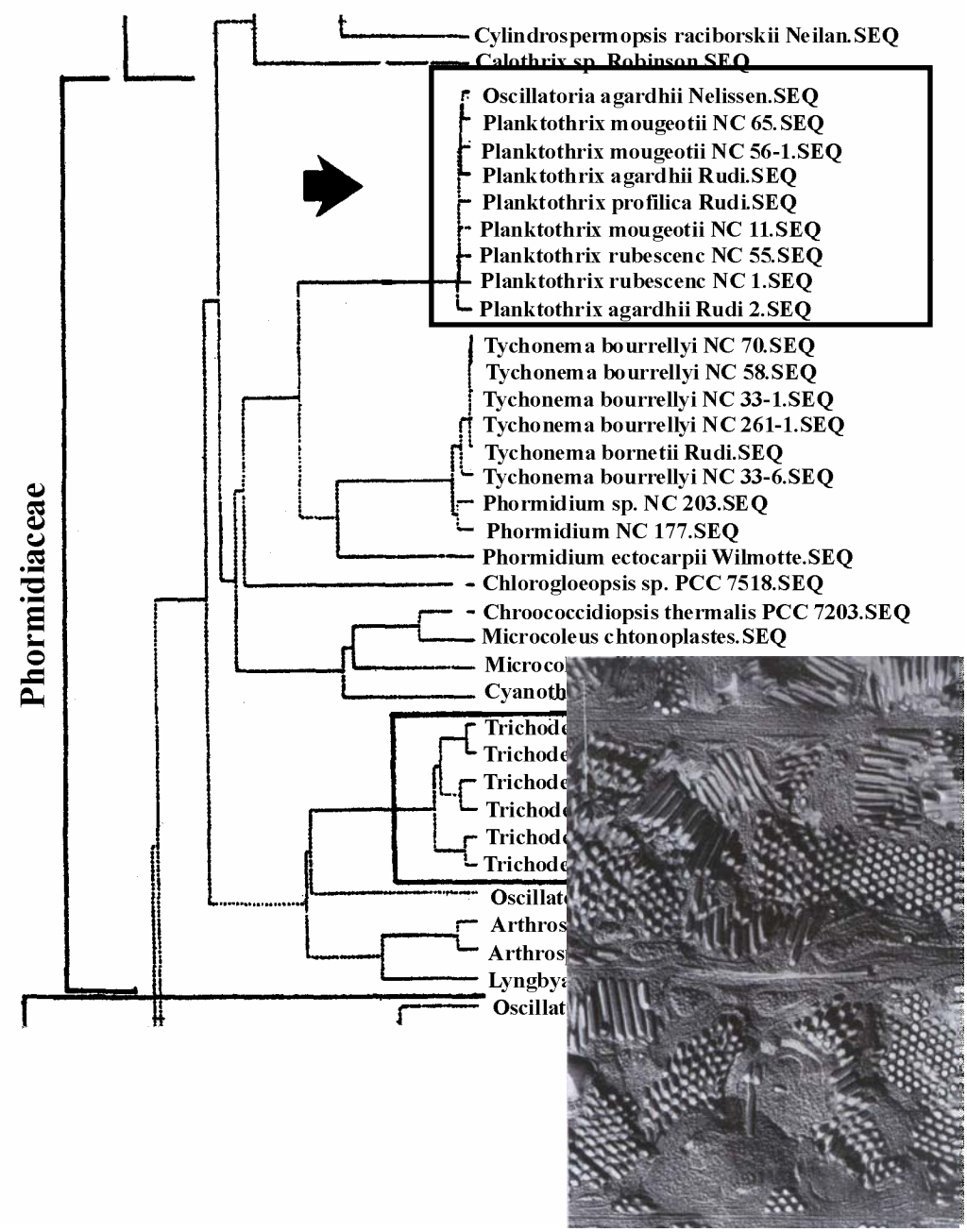


Fig. 1. Part of a phylogenetic tree constructed by Megalign (DNAStar Inc.) containing the phormidiacean genera (sequences by GeneBank of NCBI, February 2002). The genus *Planktothrix* forms a separate cluster (arrow). The ultrastructure of cells with distinct gas vesicles after ŠMARDA from KOMÁREK (2003).

According to the filament- and cell- morphology, ultrastructure (thylakoid patterns), and particularly according to the position in phylogenetic trees (Figs. 1, 2), the genera *Planktothrix* and *Planktothricoides* belong to the family *Phormidiaceae* (order *Oscillatoriales*). In the present review, the knowledge concerning the variability and diversity of both genera is summarized.

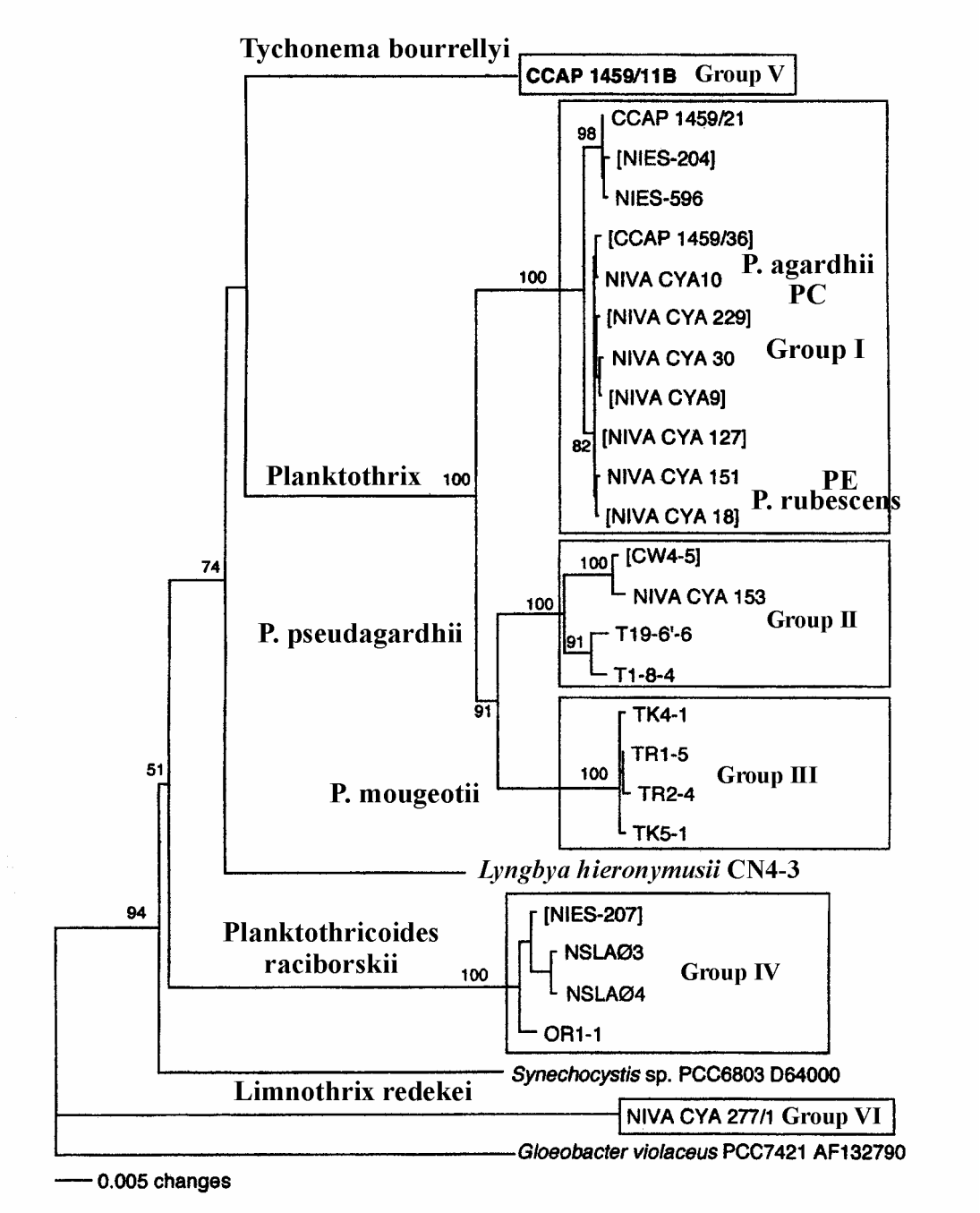


Fig. 2. Evaluation of *Planktothrix* species and related planktic phormidiacean genera according to genetic, biochemical and ecophysiological characters. *P. mougeotii* in the sense of SUDA et al. (2002). From SUDA et al. (2002), sec. KOMÁREK (2003b).

Results

Description of the genera *Planktothrix* and *Planktothricoides*

Planktothrix ANAGNOSTIDIS et KOMÁREK, Algolog. Studies 50-53: 414, 1988.

Trichomes solitary, free-floating, more or less straight or slightly irregularly waved or curved, isopolar, cylindrical, not constricted or (usually slightly) constricted at cross-walls, mainly planktic, rarely metaphytic, in mass developments (in water blooms) gathered into free, disintegrating, irregular clusters; length of trichomes up to 4 mm, width (2.3)3 – 12(15) μm, immotile, or occasionally slightly motile (trembling, gliding), slightly attenuated or not attenuated towards the ends, sometimes capitated or with terminal calyptras. Short segments of trichomes with cells without prominent aerotopes (probably diazocytes) occur occasionally in all the species and are characteristic for the whole genus.
Sheaths (or mucilaginous envelopes) lack in majority of species, or they are slightly developed only under stress conditions; in this case, they are fine, colourless and diffluent. In one metaphytic species (*P. cryptovaginata*), the facultative, thin and colourless sheaths are present obligatory in nature. However, the classification of this species in the genus *Planktothrix* has not been proved by biochemical or molecular methods yet. False branching has never been observed.
Cells cylindrical or (rarely) slightly barrel-shaped, shorter than wide, up to ± isodiametric or (again rarely) little longer than wide; thylakoids ± radially arranged, gas vesicles (grouped in aerotopes) distributed obligatorily over the whole protoplast. Apical cells when fully developed rounded or narrow-conical, sometimes with calyptra or only with thickened outer cell wall. Chromatic adaptation was not recorded, however, various species (morpho- and ecotypes ?) possess the constant phycocyanin/ phycoerythrin ratio (PC:PE). Moreover, the carotenoids myxoxanthophyll and oscillaxanthin are probably characteristic for the whole genus (SKULBERG & SKULBERG 1985). Facultative production of geosmin and cyanotoxins were found in several strains. GC (guanin-cytosin) content = about 40 mol %.
Type species: *Oscillatoria agardhii* GOMONT, Ann. Sci. Nat. VII. Bot.16: 205, 1892 = *P. agardhii* (p. 15).

Planktothricoides SUDA et M.M.WATANABE in SUDA et al., Int. J. Syst. Evol. Microbiol. 52: 1593, 2002.

Trichomes solitary, free-floating, generally straight or slightly arcuated, attenuated towards ends and sometimes slightly bent near the apex, isopolar, slightly constricted or unconstricted and not granulated at cross-walls, usually

planktic, (5)6-11.2 µm wide, slightly motile (?). Occasionally appearing "thick sections" (SUDA et al. 2002) in single trichomes were found in field samples as well as in cultures.
Sheaths occur occasionally, very thin, colourless.
Cells cylindrical, shorter than wide, isodiametric (up to longer than wide ?), cell length to cell width ratio from 2:7 to 1:1. Small aerotopes are scattered at the periphery of vegetative cells; they easily rupture under stress conditions (e.g., during observation under light microscope). Apical cells rounded, conical, ± tapered, sometimes bent but not sharply pointed, without calyptra. PE is absent and complementary chromatic adaptation has never been observed. Nothing is known about cyanotoxins. GC content = 44 mol %.
Type species: *Oscillatoria raciborskii* WOŁOSZYŃSKA Bull. Int. Acad. Sci. Cracovie, Mat.-Nat., ser. B, 6B: 686, 1912 = *P. raciborskii* (p. 10)

Intrageneric diacritical characters

Both the genera *Planktothrix* and *Planktothricoides* represent genetically two delimited clusters. They are well separated from other related oscillatorialean planktic genera (*Tychonema, Limnothrix*) by position in phylogenetic trees (Figs 1,2), as well as according to the phenotypic and cytological characters (ANAGNOSTIDIS & KOMÁREK 1988, CASTENHOLZ 2001, KOMÁREK 2003b, SUDA et al. 2002). In spite of the clear molecular definition of both genera, the intrageneric classification (particularly inside of the genus *Planktothrix*) is difficult. Several traditional "species" were described inside the wide diversity of this genus according to usual morphological and ecological criteria, but their definitions were not clearly supported by results from experimental studies (Fig. 1). Several authors did not find any objective (molecular) differentiating criteria within the genus *Planktothrix* (BEARD et al. 1999, HUMBERT & LEBERRE 2001, etc.), and considered almost the whole genus as monospecific. However, evaluations of the variability of *Planktothrix* specimens from strains, as well as from natural populations on the basis of combined (polyphasic) approach, were also already published. Such studies should be a good basis for a final solution of natural diversity and taxonomic classification within both genera (SKULBERG & SKULBERG 1985, SUDA et al. 2002, DAVIS et al. 2003). This review presents the recent knowledge of the problem.

Main intrageneric characters:

(i) C o l o u r a t i o n: this distinct and constant character depends on the stable PE:PC ratio. Chromatic adaptation has never been found (SKULBERG & SKULBERG 1985, SUDA et al. 2002) and genetic stability of PE production in different genotypes (species) was explained by DAVIS et

al. (2003). The red types (*P. rubescens*-complex) can be classified separately from green types (*P. agardhii*-complex), and this character can be therefore used also for taxonomic identification (Fig. 3).

(ii) D i m e n s i o n s, width of trichomes: this character is rather unstable; a variability in size of trichomes was particularly demonstrated in the recent studies (SUDA et al. 2002, DAVIS et al. 2003). The width of the trichomes is still used in the traditional description of the species, but hardly can be used as a decisive for separation of taxonomic groups. It concerns mainly the following taxa:

- *Planktothrix prolifica/P. rubescens*-complex: both described species differ mainly by dimensions. The wide variability of dimensions was proved by DAVIS et al. (2003). If another feature differentiating both species is not found, their acceptance is not possible. However, up to now it seems that both species have also different distribution; *P. prolifica* was mostly identified in North America. It is also possible, that this species is more distributed in Nordic lakes, so that it corresponds rather to „red *Planktothrix agardhii*" (compare, e.g., with results of SKULBERG & SKULBERG 1985 and WALSBY et al. 1983).

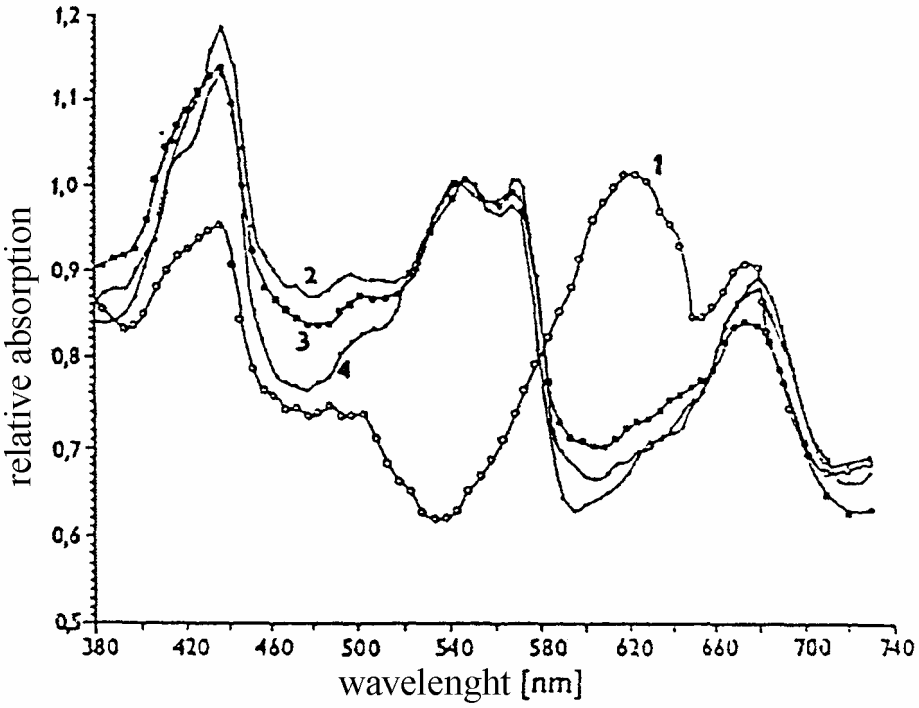


Fig. 3. Composition of phycobilins (spectral analysis) from *P. rubescens* (1) and three strains of *P. agardhii* (2-4) from KOMÁREK (2002).

- *Planktothrix compressa/P. clathrata*: This cluster contains populations with cylindrical trichomes, not narrowed to the ends, not capitate, with cells always shorter than wide and with distinct constrictions at the cross-walls. Both species belong to „thicker" types and distinguish only slightly by dimensions. They are probably conspecific and the valid specific name should be „*P. compressa"*. However, just the description of this species is incomplete. Morphologically very similar is also *P. mougeotii* sensu SUDA et al. (2002).
- *Planktothrix agardhii/P. suspensa:* The separation of both these species is doubtful according to present criteria (DAVIS et al. 2003). However, similarly as in *P. prolifica/P. rubescens,* it is necessary to prove whether other characters exist which would distinguish both these *Planktothrix*-types. Moreover, another species from this morphotype has been recently described (*P. pseudagardhii*). According to our opinion, relations between all these types should be studied more in detail. In spite of transient populations and wide variability in size in cultures, also populations of very distinct and limited trichome-widths exist in nature.

(iii) C o n s t r i c t i o n s at cross walls. The constrictions at the cross walls is a variable character, however, some morphotypes exist, which never have constricted cross-walls visible in optical microscope (slightly visible constrictions are evident only at high magnifications or in EM), e.g. *P. isothrix.* On the other hand, always visible constrictions are in the complex of species *P.compressa/P.clathrata* and in *P. arnoldii.*

(iv) A p i c a l c e l l s, morphology, calyptras: Morphology of apical cells in well developed trichomes is evidently a stable character. Types with distinct calyptrate apical cells (*P. agardhii, P. rubescens*, both with triangular calyptras in old trichomes) are well distinguishable from types with narrowed cells and only low rounded calyptra (or thickened outer cell wall: *P. pseudagardhii, P. clathrata, P. isothrix*). *P. isothrix* and *P. compressa/clathrata*-types have cylindrical, almost not attenuated trichome ends, but they differ by cell morphology one from another.

Note: The problem of the original concept of *P. mougeotii* is connected with characters discussed under (iii) and (iv). Original concept is not clear (compare SUDA et al. 2002). This species has cylindrical trichomes along the whole length, which can be only very indistictly narrowed toward the ends. The apical cell is also cylindrical, widely rounded, never capitate and not calyptrate, only sometimes with slightly thickened outer cell wall. The cells are or ± isodiametric, never constricted at cross-walls according to original drawing of KÜTZING (see e.g. in STARMACH 1966); this concept is probably identical with *Phormidium formosum*, but the epithet „*mougeotii*" was later used also for planktic populations designated, e.g., as as „*Oscillatoria mougeotii* var. *isothrix*" by SKUJA (1948). SUDA et al. (2002) designated another type with this name (based on *Oscillatoria mougeotii* KÜTZ. ex LEMM. 1907), which

corresponded rather to *P.compressa/P. clathrata* - complex (short cells and constrictions at cross walls). Filaments which corresponded to *O. mougeotii* var. *isothrix* probably have not been included in the study of SUDA et al. (2002).

(v) G a s v e s i c l e s are characteristic for both discussed genera, but differences in GV-genotypes were found between *Planktothrix* and *Planktothricoides* by SUDA et al. (2002), and also between green-coloured *P. agardhii* – group and red-coloured *P. rubescens*–group (DAVIS et al. 2003). While different size of gas vesicles has not probably taxonomic value, the different GV-genotypes can be used to the complex evaluation of the intrageneric diversity (DAVIS et al. 2003).

Phenotype key to the identification of *Planktothrix* and *Planktothricoides* species

In the following key and review were included all the up to date described *Planktothrix* –taxa. However, it is probable, that several of them (particularly these ones, which differ only by dimensions; e.g., *P. suspensa, P. prolifica*) belong into the size ranges of other described species. Their identity or separation (in respect to other characters) should be proved by further studies. Up to now, the review of all described species seems to be useful for further studies.

1a Gas vesicles in cells concentrated in peripheral parts of cells, unstable and easily rupturing; richomes toward the ends always narrowed and not calyptrate: ***Planktothricoides*** **…….. 2**

1b Gas vesicles spread over the whole cell volume, ± stable; trichomes towards ends not attenuated, or attenuated, and in this case often calyptrate or capitate (in well developed trichomes): ***Planktothrix*** **……..…… 3**

2a Developed trichomes 5.4-12.2 μm wide, at the ends ± shortly narrowed and sometimes bent; apical cells sometimes conical and roundly-pointed **…….**
1. *P-s. raciborskii*

2b Developed trichomes 3.5-6.8 μm wide, at the ends gradually narrowed and always straight;
apical cells narrowed and widely rounded **…… 2. *P-s. attenuata***

3a Filaments usually distinctly wavy and coiled, long, trichomes slightly or clearly constricted at cross-walls; usually metaphytic in littoral (among water plants or on stones); facultative sheaths in vegetative state **……...… 4**

3b Filaments usually straight or slightly curved; trichomes not constricted or constricted at cross-walls; usually free-floating, planktic; sheaths occur only under stress conditions **……...… 5**

4a Filaments irregularly wavy and coiled, usually with sheaths; trichomes 4-8.5 µm wide, with sheaths up to 9 µm wide; in metaphyton among water plants **…… 3. *P-x. cryptovaginata***
4b Filaments irregularly wavy and sometimes screw-like coiled towards ends, usually without sheaths; trichomes 7.5-11.5 µm wide; in littoral of clear water bodies, secondary in plankton…**…….. 4. *P-x. planctonica***

5a Trichomes reddish or pinkish red (high content of PE); in mass populations form reddish water blooms **…..…….. 6**
5b Trichomes blue-green, pale or dark blue-green, or yellowish green, never reddish (sometimes dark for plenty of aerotopes) **……..…….. 7**

6a Trichomes always less than 6 µm wide **……..…….. 5. (*P-x. prolifica*)**
6b Trichomes usually more than 6µm wide (4-9 µm) **…… 6. *P-x. rubescens***

7a Trichomes distinctly constricted at cross-walls; cells always shorter than wide **……. 8**
7b Trichomes not constricted or only occasionally slightly constricted at cross-walls; cells usually ± isodiametric, or shorter and sometimes longer than wide (always shorter cells only in *P-x. geitleri* and *P-x. pseudagardhii*) **……..…… 10**

8a Well developed trichomes 9-10 µm wide, slightly narrowed toward the ends and terminated by flat, hyaline, widely rounded cells (in form of large calyptra); known only from saline waters in Aral Sea, central Asia **……...……...… 7. *P-x. arnoldii***
8b Trichomes cylindrical along the whole cell length, not attenuated, apical cells widely rounded, only sometimes with thickened outer cell wall **…… 9**

9a Trichomes 5-6(8) µm wide **…….…….. 8. (*P-x. clathrata*)**
9b Trichomes 5.9-8(9.5) µm wide **……..… 9. *P-x. compressa***

10a Trichomes cylindrical, not attenuated towards ends, apical cells widely rounded **……..….. 11**
10b Developed trichomes slightly narrowed towards ends and often with calyptrated apical cells **……..……. 12**

11a Trichomes 2.5–3.5 µm wide, with 1-3 aerotopes in cells; known only from polluted ponds near Peshawar, Pakistan **……..…….. 10. *P-x. zahidii***
11b Trichomes (5)5.5-10 µm wide, with numerous aerotopes in cells („dark cells“) **…….……..…. 11. *P-x. isothrix***

12a Cells always shorter than wide, trichomes without high, triangular calyptra **…….. 13**
12b Cells ± isodiametric, shorter than wide, or sometimes longer than wide, well developed trichomes often with calyptrate terminal cell (with ± triangular calyptra) **…… 14**

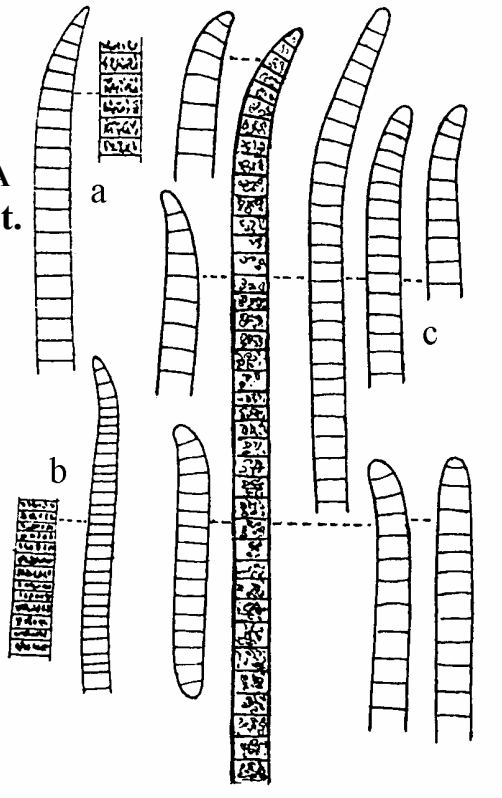
13a Trichomes 5-11 μm wide; terminal parts of trichomes often distinctly narrowed, end cells capitate, but without calyptra; halophilic, known only from central Asia **……..… 12. *P-x. geitleri***
13b Trichomes 3-6.4 μm wide; terminal parts of trichomes very slightly narrowed, apical cells variable, but ± outside rounded (occasionally capitate); calyptra (if present) narrow, rounded **…… 13. *P-x. pseudagardhii***

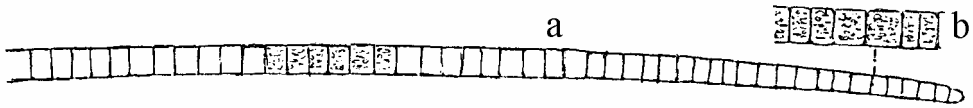
14a Trichomes 2-4 μm wide, yellowish green; cells ± isodiametric or sometimes longer than wide **……..…….…… 14. (*P-x. suspensa*)**
14b Trichomes 2.3-9.8 μm wide, blue-green; cells isodiametric or shorter or longer than wide **…….…….. 15. *P-x. agardhii***

List of species

1. *Planktothricoides raciborskii* (WOŁOSZ.) SUDA et M.M.WATANABE in SUDA et al., Int. J. Syst. Evol. Microb. 52: 1593, 2002

Colour: pale olive-green
Trichome-width: 5.4-12.2 μm
Constrictions: -
Trichome ends: shortly narrowed
Apical cells: sometimes bent, rounded conical, without calyptra
Distribution: tropical, subtropical (Africa, Asia) particularly SE Asia
Synonyms: *Oscillatoria raciborskii* WOŁOSZ. 1912
Planktothrix raciborskii (WOŁOSZ.) ANAGN. et KOM.1988



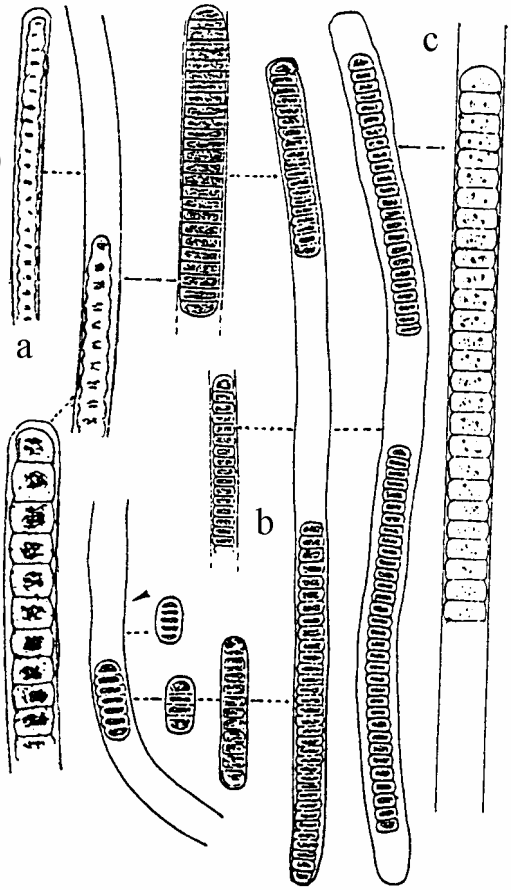


2. *Planktothricoides attenuata* KOM. et KOM.-LEGN., Preslia 2004 (in press)

Colour: pale olive-green or blue-green
Trichome-width: 3.5-6.8 µm
Constrictions: - (very slightly +)
Trichome ends: straight, continually narrowed
Apical cells: slightly narrowed, widely rounded ends
thickened outer cell wall, without calyptra
Distribution: free-floating, tropical lakes (pantropical?)
Synonyms: ---

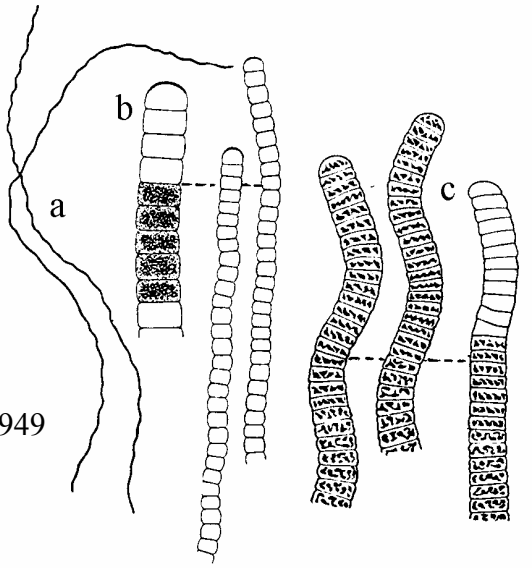
3. *Planktothrix cryptovaginata* (ŠKORB.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

Colour: pale blue-green
Trichome-width: 4-8.5(9) µm
Constrictions: +
Trichome ends: cylindrical, not narrowed
Apical cells: not attenuated, widely rounded
Distribution: freshwater, metaphytic or
tychoplanktic, ponds and backwaters;
central Europe and SW Asia
Synonyms: *Lyngbya cryptovaginata* ŠKORB. 1923



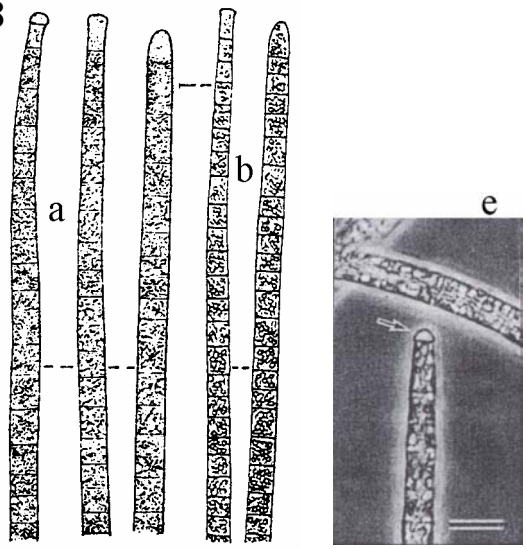
4. *Planktothrix planctonica* (ELENK.) ANAGN. et KOM., Algolog. Stud 50-53: 416, 1988

Colour: blue-green
Trichome-width: 7.5-11.5 µm
Constrictions: +
Trichome ends: cylindrical, not narrowed
Apical cells: not attenuated, widely rounded
Distribution: freshwater, in littoral, second. planktic;
central and E Europe
Synonyms: *Oscillatoria ornata* f. *planctonica* ELENK. 1949



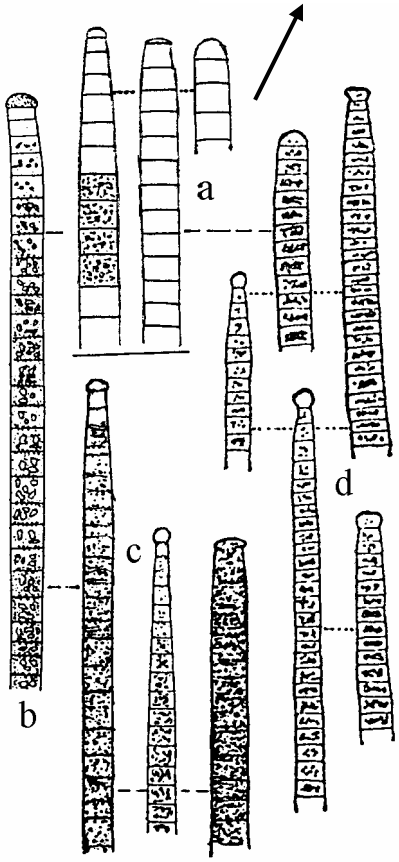
5. *Planktothrix prolifica* ([GREV.]GOM.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

Colour: reddish, pinkish-violet
Trichome-width: < 6 μm (2-5.8);
Constrictions: -
Trichome ends: gradually narrowed
Apical cells: narrowed, with triangular calyptra
Distribution: freshwater, colder lakes; central and N Europe, N America
Synonyms: *Oscillatoria prolifica* GOM. 1892



6. *Planktothrix rubescens* (DC. ex GOM.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

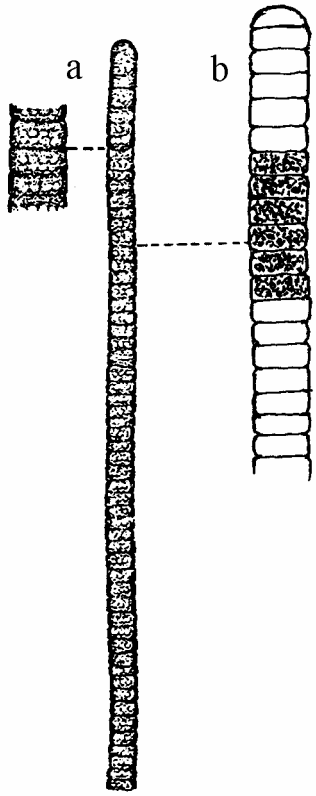
Colour: reddish
Trichome-width: 3.9-9.4 μm
Constrictions: -
Trichome ends: narrowed
Apical cells: narrowed, with triangular calyptra
Distribution: freshwater, planktic in lakes; central (northern of 42°N), northern and NE Europe, NE USA
Synonyms: *Oscillatoria rubescens* DC ex GOM. 1892
? *O. rubescens* var. *caucasica* SCHMIDLE 1897



7. *Planktothrix arnoldii* (KISEL.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

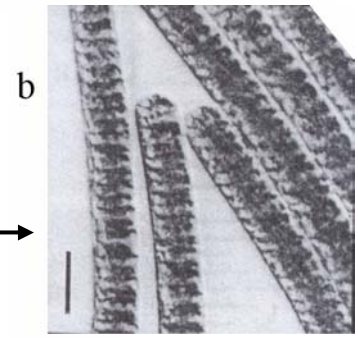
Colour: blue-green
Trichome-width: 9-10 μm
Constrictions: +
Trichome ends: continually narrowed (irreg.)
Apical cells: narrowed, rounded, sometimes capitate (hyaline, widely rounded cell – "oval" calyptra)
Distribution: Kazakhstan/Uzbekistan, planktic in Aral Sea
Synonyms: *Oscillatoria (Oscillaria) arnoldii* KISEL. 1927

8. *Planktothrix clathrata* (SKUJA) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988



Colour: blue-green
Trichome-width: 5-8(-9?) μm
Constrictions: +
Trichome ends: not attenuated, cylindrical
Apical cells: widely rounded, without calyptra
Distribution: freshwater, benthic and planktic in lakes; central and N Europe, Australia?
Synonyms: *Oscillatoria mougeotii* var. *clathrata* SKUJA 1956

9. *Planktothrix compressa* (UTERM.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

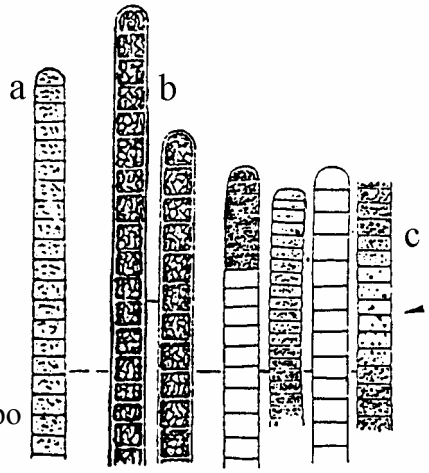


Colour: blue-green
Trichome-width: 5-9.5 μm
Constrictions: +
Trichome ends: not attenuated, cylindrical
Apical cells: widely rounded
Distribution: freshwater, planktic in lakes; central Europe
Synonyms: *? Oscillatoria mougeotii* KÜTZ. ex LEMM. 1907
? Planktothrix mougeotii sensu SUDA et M.M WATANABE in SUDA et al.2002
Lyngbya compressa UTERM. 1925

10. *Planktothrix zahidii* (FARIDI et KHALIL) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988

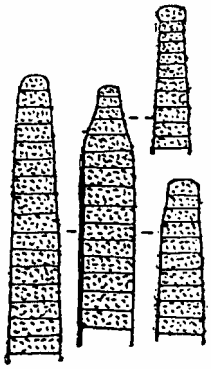
Colour: olive-blue-green
Trichome-width: 2.5-3.5 μm
Constrictions: -
Trichome ends: cylindrical, not attenuated
Apical cells: cylindrical, rounded
Distribution: polluted ponds near Peshawar, Pakistan
Synonyms: *Oscillatoria zahidii* FARIDI et KHALIL 1974

11. *Planktothrix isothrix* (SKUJA) comb. nova



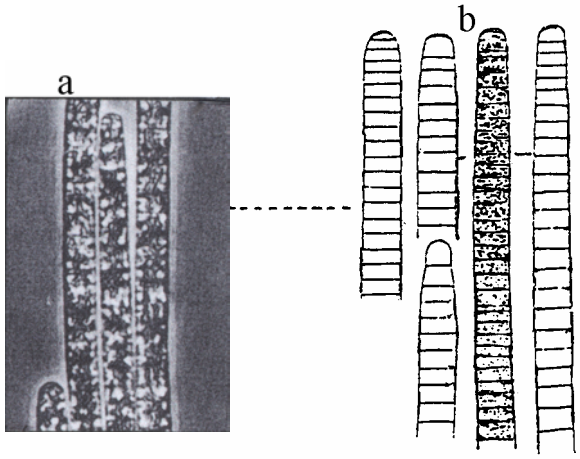
Colour: blue-green
Trichome-width: (5)5.5-10 μm
Constrictions: -
Trichome ends: cylindrical, not attenuated, or very slightly attenuated
Apical cells: cylindrical, widely rounded
Distribution: eutrophic (to hypertrophic) reservoirs; cosmopolitan?
Synonyms: *Oscillatoria mougeotii* BORY ex GOM. 1892 sine typo
Planktothrix mougeotii (BORY ex GOM.) ANAGN. et KOM. 1988 sine typo
Oscillatoria agardhii var. *isothrix* SKUJA, Symb. bot. Upsal. 9(3): 49, 1948 (basionym)

12. *Planktothrix geitleri* (KISEL.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988



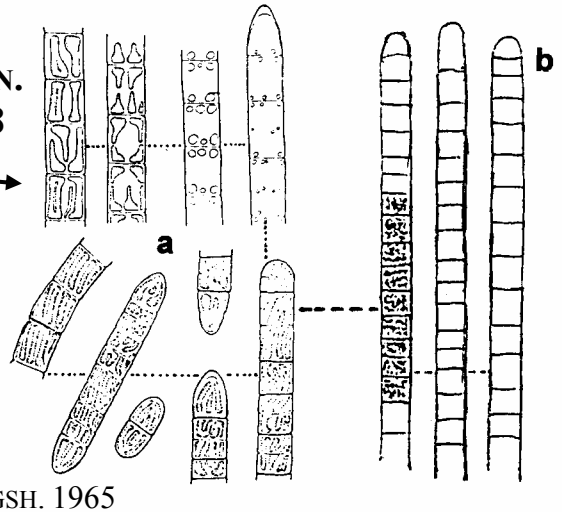
Colour: blue-green
Trichome-width: 5-11 μm
Constrictions: - (or very slightly +)
Trichome ends: slightly (sometimes abruptly) attenuated, morphol. variable
Apical cells: conical, widely rounded-obtuse, sometimes capitate, not calyptrate
Distribution: slightly halophilic, reservoirs of central Asia (Aral Sea)
Synonyms: *Oscillatoria (Oscillaria) geitleri* KISEL. 1927

13. *Planktothrix pseudagardhii* SUDA et M.M.WATANABE in SUDA et al., Int. J. Syst. Evol. Microb. 52: 1593, 2002



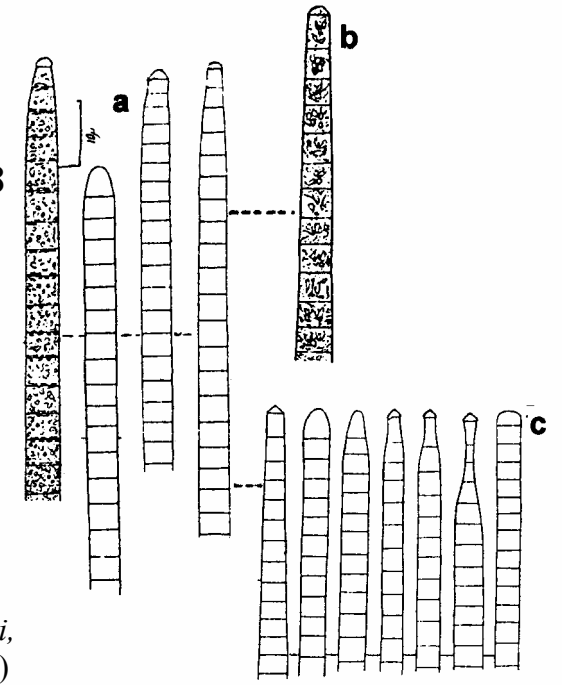
Colour: pale blue-green, blue-green or yellowish
Trichome-width: 3-6.4 μm
Constrictions: -
Trichome ends: slightly attenuated
Apical cells: tappered-rounded, bluntly conical; sometimes small calyptra
Distribution: freshwater, planktic; probably over whole temperate zone, (cosmopolitan?)
Synonyms: ---

14. *Planktothrix suspensa* (PRINGSH.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988



Colour: yellow-green, olive-green or blue-green
Trichome-width: 2-4 µm
Constrictions: -
Trichome ends: slightly narrowed
Apical cells: ± cylindrical or conical rounded, sometimes calyptrate (narrow calyptra)
Distribution: freshwater, mesotrophic to eutrophic reservoirs; central Europe
Synonyms: *Oscillatoria agardhii* var. *suspensa* PRINGSH. 1965

15. *Planktothrix agardhii* (GOM.) ANAGN. et KOM., Algolog. Stud. 50-53: 416, 1988



Colour: blue-green
Trichome-width: 2.3-9.8 µm
Constrictions: - (or slightly +)
Trichome ends: continually narrowed
Apical cells: narrowed, triangular calyptra
Distribution: freshwater – planktic; cosmopolitan?, mainly eutrophic reservoirs in temperate zone; tropical regions?
Synonyms: *Oscillatoria agardhii* GOMONT 1892 (including all forms described by ELENKIN 1949: f. *aequicrassa,* f. *moebiusii,* f. *lemmermannii,* f. *gomontii,* f. *wislouchii*)

Other possible *Planktothrix*-like descriptions, which need revision:

Oscillatoria baltica EBERLY 1966: free-floating in Baltic Sea.
Oscillatoria (Trichodesmium?) lacustris var. *solitaria* BEHRE 1956: probably distinct, separate species (pantropical?: Brazil, Philippines, South Africa).
Oscillatoria lutescens PANKOW et JAHNKE 1964: from a village pond near Rostock, N Germany.
Oscillatoria mehrai VASISHTA 1963: from road-side pond, India.
Oscillatoria miyadii NEGORO 1943: from Japan.
Oscillatoria pseudomougeotia VASISHTA 1962: from India.
Oscillatoria rileyi DROUET 1944: from a pond in USA (Conn.).
Oscillatoria rubescens forma *ahmedabadensis* KAMAT 1962: from moist soil, India.
Oscillatoria rubescens sensu COMPÈRE 1974: from lake Chad.
Oscillatoria rubescens sensu TIWARI 1975: from paddy field soils, India.

Oscillatoria setigera APTEKAR' 1928: with sharply pointed ends, from Ukraine.
Oscillatoria subbrevis sensu HAUGHEY 1969: water bloom in oxidation pond, New Zealand.

Notes to figures in list of species

1. *Planktothricoides raciborskii*: **a** – after WOŁOSZYŃSKA from STARMACH (1966); **b** - after WOŁOSZYŃSKA from HUBER-PESTALOZZI (1938); **c** – after KOMÁREK & CRONBERG (2002).
2. *Planktothricoides attenuata*: **a-b** – after KOMÁREK et al. (2004).
3. *Planktothrix cryptovaginata*: **a** – after ŠKORBATOV from STARMACH (1966); **b** – after SKÁCELOVÁ & KOMÁREK (1989).
4. *Planktothrix planctonica*: **a-b** – after COMPÈRE et al. (1979); **c** – after ELENKIN from KONDRATEVA (1968).
5. *Planktothrix prolifica*: **a** – after G.M.SMITH (1920); **b** – after PRESCOTT (1962).
6. *Planktothrix rubescens*: **a** – after KOMÁREK (1988); **b** – after PRESCOTT (1962); **c** – after STARMACH (1966); **d** – after THOMAS (1976); **e** – after SUDA et al. (2002).
7. *Planktothrix arnoldii*: after KISELEV (1927).
8. *Planktothrix clathrata*: **a** – after SKUJA (1956); **b** – orig. from lakes near Berlin, Germany.
9. *Planktothrix compressa*: **a**- after UTERMÖHL (1925); **b** – *Planktothrix mougeotii* sensu SUDA et al. (2002).
10. *Planktothrix zahidii*: after FARIDI & KHALIL (1974).
11. *Planktothrix isothrix*: **a** - after KÜTZING from STARMACH (1966); **b** – after SKUJA (1948); **c** – after KOMÁREK (1984).
12. *Planktothrix geitleri*: after KISELEV (1927).
13. *Planktothrix pseudagardhii*: **a** – after SUDA et al. (2002); **b** – after KOMÁREK (1984, sub *P. agardhii* – Cuban population, morphologically correponds rather to *P. pseudagardhii*).
14. *Planktothrix suspensa*: **a** – after PRINGSHEIM (1965); **b** – after KOMÁREK (1996).
15. *Planktothrix agardhii*: **a** – after KOMÁREK (1958); **b** – after GEITLER (1932); **c** – after WISLOUCH from GEITLER (1932).

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