Two *Camptylonemopsis* species (cyanoprokaryotes) from "Mata Atlantica" in coastal Brazil

Dva druhy rodu *Camptylonemopsis* (*Cyanoprokaryota*) z pobřežních tropických lesů „Mata Atlantica" v Brazílii

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Two new species of the genus *Camptylonemopsis* (*Cyanoprokaryota, Cyanobacteria*), namely *C. epibryos* spec. nova and *C. sennae* spec. nova, are described from the coastal tropical rainy forest "Mata Atlantica" in Brazil (state São Paulo). The diacritical features and the taxonomic position of the genus, particularly the comparison with the related genera *Coleodesmium, Tolypothrix* and *Scytonema* are discussed. The tabular review of the genus *Camptylonemopsis* is presented.

K e y w o r d s : *Camptylonemopsis, Cyanobacteria, Cyanoprokaryota* , tropical species, taxonomy, life cycle, distribution, Brazil

Introduction

The cyanoprokaryotic genus *Camptylonemopsis* Desikachary 1948 is known mainly from tropical biotopes in India, Pakistan, and two species were found in Russia and China. Eight species were described up to now altogether. The genus is classified into the family *Scytonemataceae* according to morphology of filaments, formation of intercalar heterocytes, life cycle (particularly according to characteristic isopolar germination of hormogonia with central heterocytes), trichome structure, type of trichome disintegration, and occasional false branching of the tolypotrichoid or scytonematoid type. It differs phenotypically from the genera *Scytonema* and *Tolypothrix* by presence of akinetes in several species (according to Desikachary 1948, 1959), by absence of typical growth form with common scytonematoid or tolypotrichoid branching, and by formation of thallus with more or less parallel arranged isopolar filaments within a colony. From the genus *Coleodesmium* it differs by isopolar growth and creeping central parts of filaments.

Recently, two *Camptylonemopsis* populations were studied from samples collected in two Brazilian localities in regions of the tropical forests of E coast of South America in 1996 and 2000 (in rainy forest formation "Mata Atlantica"), which do not correspond to any known species. They are the first *Camptylonemopsis* species found in American continents. *C. epibryos* sp. nova was found as an epiphyte in submersed mosses in very clean, acidic, natural ponds called "restingas"; *C. sennae* sp. nova was collected from wet stones and other substrates in streaming creek (subaerophytically on the edge of water). Both new species are compared with up to date described species from tropical Asia and from Russia.

Results

Camptylonemopsis epibryos Komárek **spec. nova**

Diagnosis: Fila solitaria, irregulariter circinata, repentia ad muscos aquaticos, submersos, cylindrica, 15–16.5 μm lata, rare false ramosa; rami breves, longitudine ad fila materna conjuncta, apice late rotundata. Trichomata cylindrica, ad septa haud constricta, ad apices not attenuata, 11–14 μm lata. Vaginae cylindricae, ambitu plus minusve inaequales, mucilaginosae, lamellosae, apice clausae (apertae postea hormogonia formantur), incolores. Cellulae cylindricae, semper brevior quam latae, contentu plus minusve homogeneo, violaceo. Heterocytae intercalares, solitariae, cylindricae, plus minusve isodiametricae vel longior quam latae, 8–14 μm latae. Akinetae carentes. – Holotypus (icona typica): figura nostra 1. – Habitatio: Epiphytice ad muscos submersos in paludibus acidis "restingas" dictis, in sylvis montium "Mata Atlantica", prope oppidum Ubatuba, regio São Paulo, Brasilia. – Etymologia: Secundum modus vivendi epiphyticus ad muscos aquaticos nominata.

Description (Fig. 1): Filaments solitary, irregularly wavy, creeping on the surface of mosses (leaves, rests of plants) and woody substrates, cylindrical along the whole length, 15.0–16.5 μm wide, rounded at the end. Trichomes cylindrical, not constricted at cross walls, not attenuated towards ends, 11–14 μm wide. Sheaths attached to trichomes, thick, lamellated, colourless, closed at the ends. Cells always shorter than wide, violet, apical cells widely rounded, without calyptra. Heterocytes intercalar, solitary, cylindrical, ± isodiametric or longer than wide, usually so wide as trichomes or slightly narrower. The filaments easy fragmentate; the false branching occurs in form of parallel joined separated segments of filaments to the mother filament.

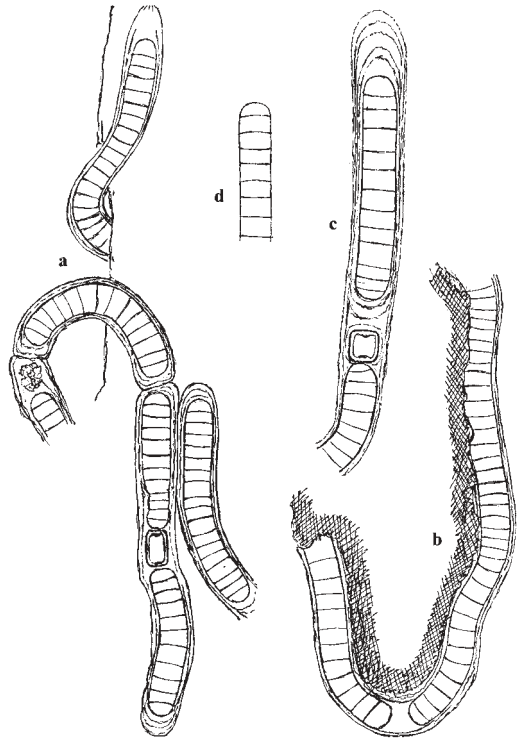


Fig. 1. – *Camptylonemopsis epibryos;* a – part of creeping filaments with typical branching and one heterocyte; b – part of a creeping filament without heterocytes; c – end of filament with a heterocyte; d – end of a trichome (orig. drawing).

E c o l o g y : The filaments grow submersely, creeping on the substrate, mainly epiphytic on benthic mosses, rarely on wood, other submerged plants and substrates. Found only in acidic shallow pools and swamps called "restingas", with common benthic moss vegetation. Near the eastern foot of mountains with tropical rainy forest "Mata Atlantica" along the eastern shore of Atlantic, Brazil, between São Paulo and Rio de Janeiro. The type material was collected from restingas near the town Ubatuba, 29. 9. 1996, from the moss *Fissidens* cf. *asplenioides*.

Camptylonemopsis sennae Komárek **spec. nova**

D i a g n o s i s : Fila in stratum macroscopicum, nigrum vel atro-aerugineum, plus minusve paralleliter in fasciculis consociata, leviter sinuata, cylindrica, 13.3–17.8 μm lata, apice rotundata. Trichomata cylindrica, ad septa haud constricta, ad apices not attenuata, 8.6–12.5 μm lata. Vaginae cylindricae, firmae, tenues sine colore et postea ad 5 μm latae, lamellosae, luteo-brunescentes, adultae apice apertae. Cellulae cylindricae, brevior vel longior quam latae, contentu plus minusve homogeneo, pallide aerugineo, griseo vel paucim violascentes, 3.2–16.5 μm longae. Heterocytae intercalares, solitariae, cylindricae, 6.8–15.4 × 10.2–11.2 μm. Akinetae carentes. – T y p u s: Exsiccatum no. BRNM/HY 1203, icona typica: figura nostra 2. – H a b i t a t i o: Subaerice ad saxa in aquis fluentibus periodicis, in fontibus rivulisque, prope oppidum Paranapiacaba, regio São Paulo, Brasilia. – E t y m o l o g i a: Species ad honorem algologi brasiliani Pedro Américo Cabral Senna nominata.

D e s c r i p t i o n (Figs. 2, 3): Filaments in flat, woolly mats, slightly wavy or coiled, mainly parallely arranged in fascicles, cylindrical along the whole length, long, 13.3–17.8μm wide, rounded at the end in young filaments. Trichomes cylindrical, not constricted at cross walls, not attenuated or widened towards ends, 8.6–12.5 μm wide. Sheaths attached to trichomes, firm, in young filaments thin and colourless, old sheaths thick, stratified and yellowish-brown, in old filaments and especially after release of hormogonia open. Cells cylindrical, variable in length, particularly in hormogonia and young trichomes short (from the length 2.2 μm), in old trichomes up to 1.6 × longer than wide. Heterocytes intercalar, solitary, cylindrical, ± so wide as the trichomes, 6.8–15.4 × 10.2–11.2 μm. The filaments sparsely with tolypotrichoid or scytonematoid branching at free ends of filaments. Reproduction by hormogonia, often only (1) 2- or few-celled.

E c o l o g y : Subaerophytic on stony (rarely also metallic) substrates, in periodical shallow streams, on the edge of streaming water. Found in springs and outflows from springs near Paranapiacaba, state of São Paulo; the type material was collected on 5 February 2000.

The life cycle of *Camptylonemopsis* and also of both our species (Fig. 4) has several characteristic features in comparison with other members of scytonematoid cyanoprokaryotes: (i) Morphology of isopolar filaments with creeping central part and erected both ends; (ii) parallel arrangement of released hormogonia and filaments; (iii) growth form in fascicles; (iv) very rare false branching of the tolypotrichoid or scytonematoid type and common false branching of the coleodesmoid type; (v) facultative formation of akinetes (confirmation is needed). The mentioned characters occur in all up to now described *Camptylonemopsis* species, with exception of the akinete formation (known only in two species).

Discussion

The cyanoprokaryotic microflora from biotopes connected with the cold rainy forest of the type "Mata Atlantica" near the E coast of Brazil is yet completely unknown. Two our scytonematoid species are evidently new taxa, which can not be described as *Tolypothrix*,

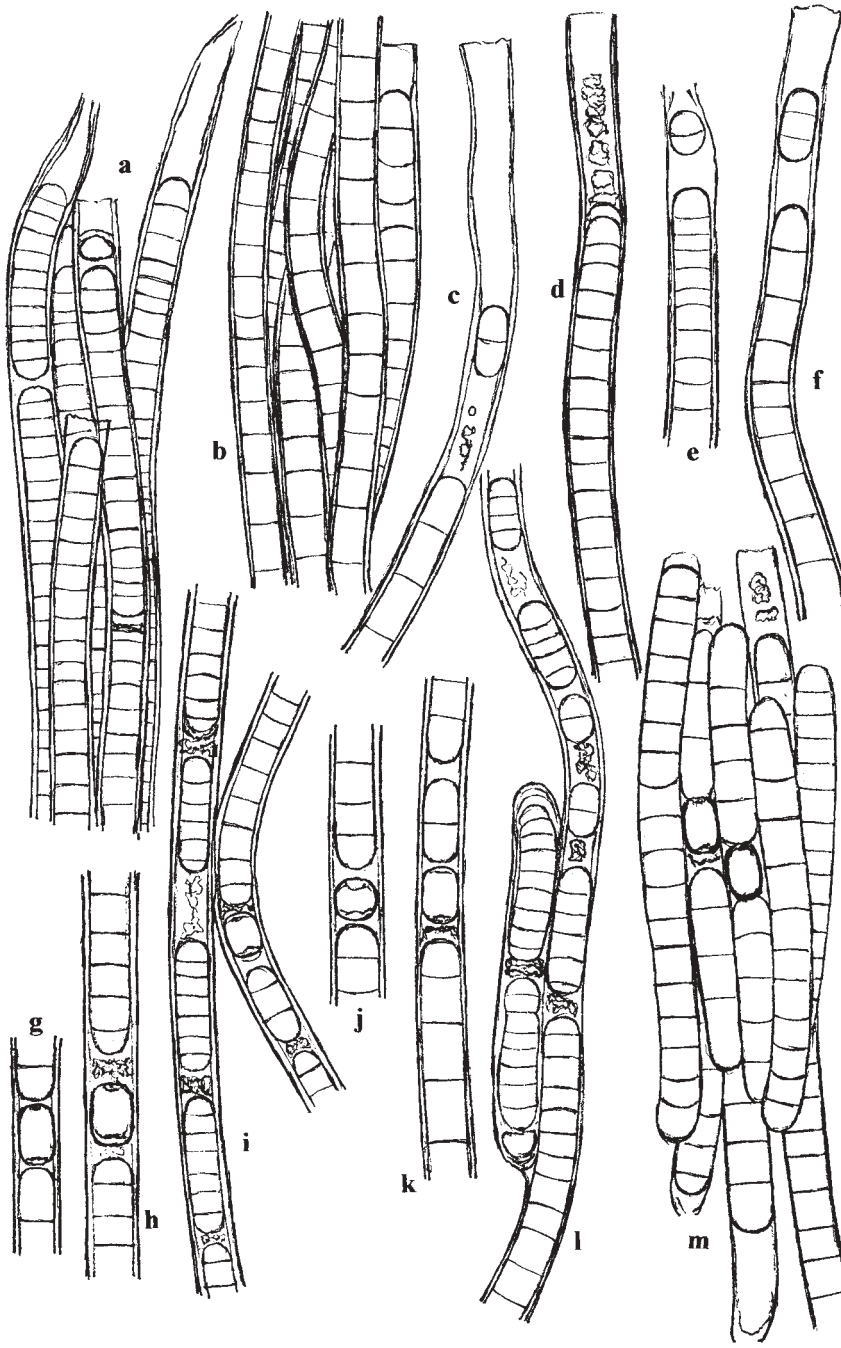


Fig. 2. – *Camptylonemopsis sennae;* a – end of fasciculated filaments; b – part of fasciculated filaments; c–f – ends of filaments, partly with formation of few-celled hormogonia; g–k – parts of filaments with heterocytes, partly with fragmentation of trichomes in hormogonia; l – part of a filaments with fragmentated trichome and typical coleodesmioid branching; m – fasciculated young trichomes with developing heterocytes (orig. drawing).

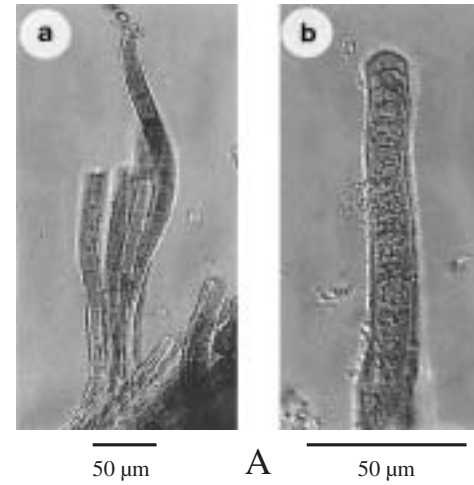
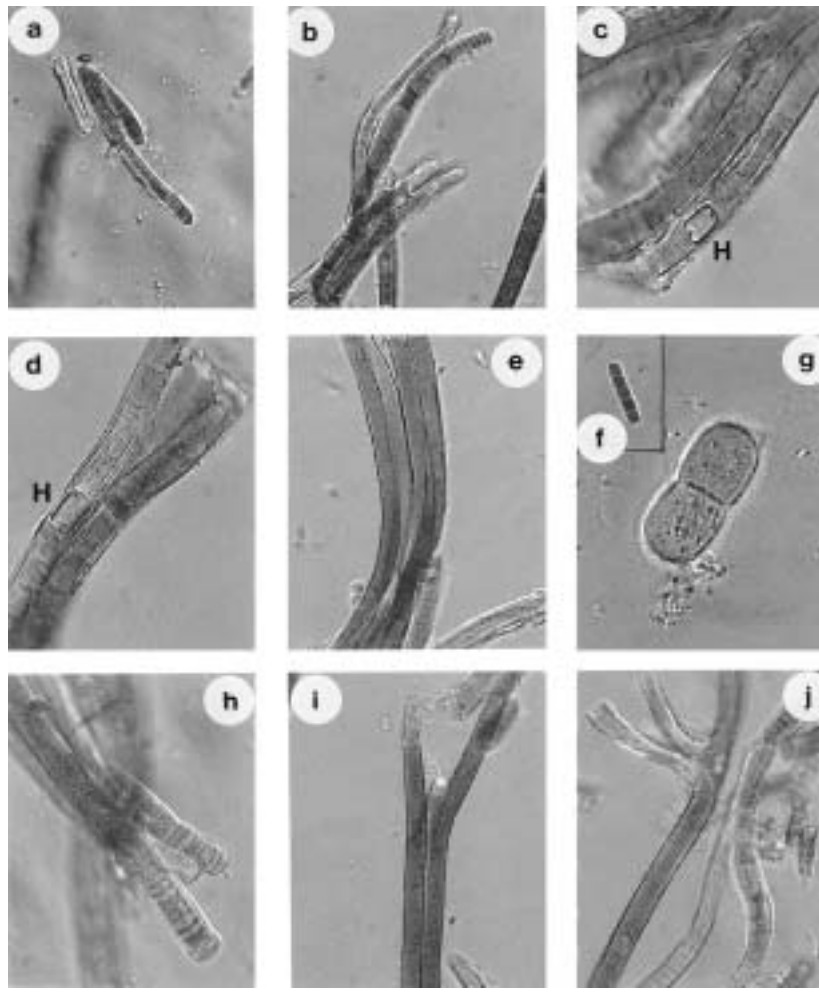


Fig. 3. – A. *Camptylonemopsis sennae;* a–b – ends of fasciculated and solitary trichomes (orig. photo J. Komárková).

B. *Camptylonemopsis sennae;* a–b – fasciculated young trichomes; c–d – trichomes with heterocytes; e – central part of fasciculated filaments; f–g – typical few-celled hormogonia; h–i – ends of fasciculated trichomes; j – rare scytonematoid branching (orig. photo J. Komárková).



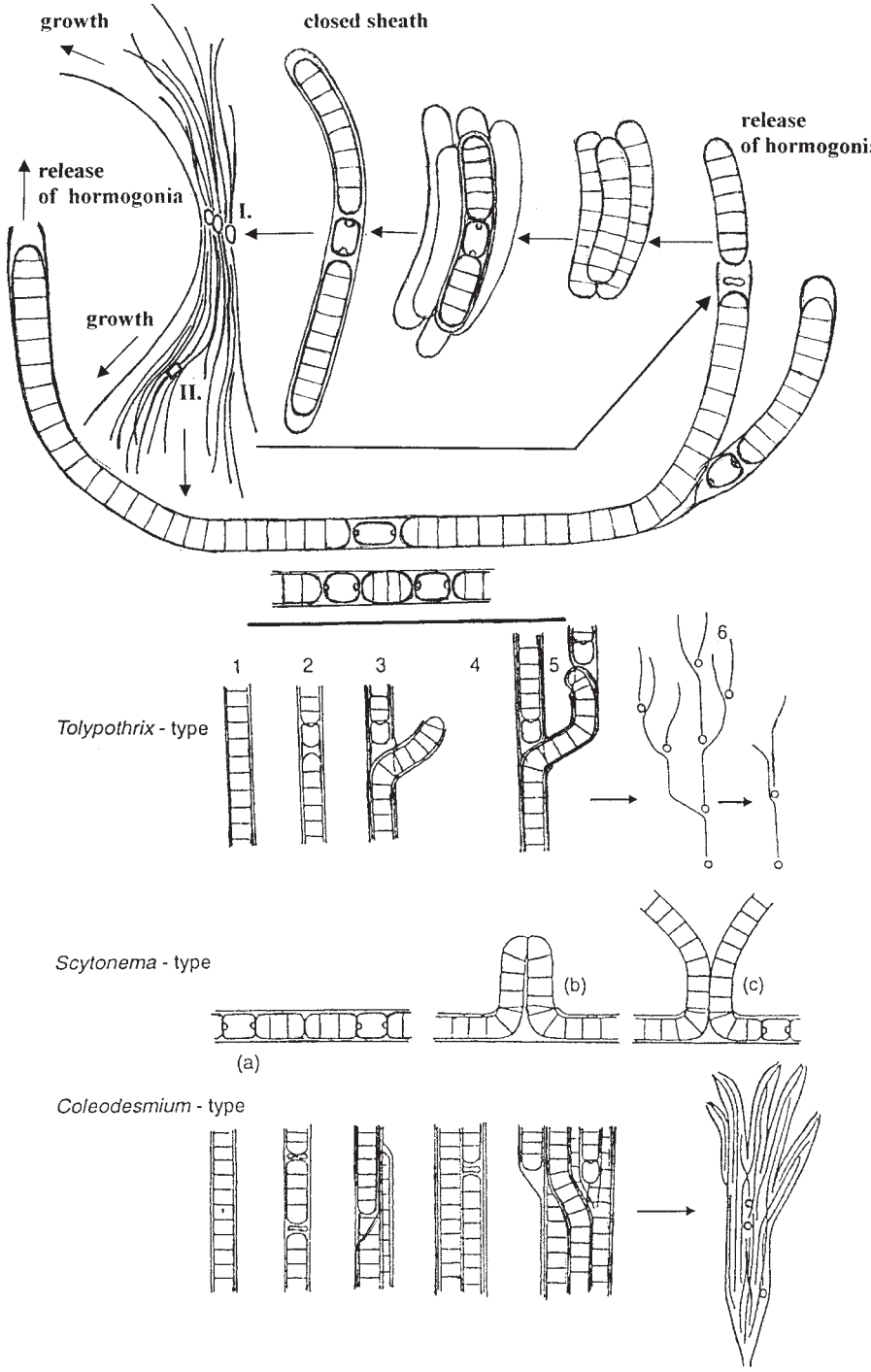


Fig. 4. – Scheme of the life-cycle of *Camptylonemopsis* (derived from *C. sennae*) (orig.); comparison with branching type of *Tolypothrix, Scytonema* and *Coleodesmium* (from Komárek 1998).

Coleodesmium or *Scytonema* species. The specific life cycle, which corresponds more or less with that one described in the genus *Camptylonemopsis* by Desikachary (1948, 1959) and Pandey (1965, sub *Tolypothrix arenophila*, follows from our studies. Our species are therefore presented under this generic name. Other *Camptylonemopsis* species are known particularly from southern, tropical Asia (India, Pakistan, S China; Ghose 1919, 1920, Desikachary 1959, Pandey & Mitra 1959, Kumar 1962, Dutt et al. 1975, Zhu 1987).

The intergeneric diacritical features in the family *Scytonemataceae* are not very distinct (Bourrelly 1985, Hoffmann 1988). It is possible to distinguish two types which develop in principle (i) heteropolar thallus with predominating false branching with one lateral branch, or (ii) group with more or less isopolar filaments and double-branched false ramification. The types from the first group (*Tolypothrix, Hassallia*, *Coleodesmium* and *Petalonema*) are sometimes classified according to their heteropolarity into the family *Microchaetaceae* (Komárek & Anagnostidis 1989). The second group is characterized mainly by isopolar growth of filaments (*Scytonema*, *Diplocolon, Scytonematopsis*). However, the distinguishing features are not well defined (Hoffmann 1988, Kukk et al. 2001), and the support of separation or unification of mentioned genera, or identity of various types must wait on the genotype analysis.

The most impressive and discussed feature of taxonomic differences within ramified cyanobacteria (*Oscillatoriaceae*, *Scytonemataceae*) is particularly the type of false branching (Bourrelly 1985, Hoffmann 1988, Watanabe & Komárek 1989, Komárek & Watanabe 1990, Komárek 1998). Divarication by one branch is typical for heteropolar genera, but scytonematoid types can also occur, and vice versa, branching with two lateral branches is not rare in old thallus of various *Tolypothrix* species. The most important feature is therefore bipolar or heteropolar development of hormogonia (Komárek & Anagnostidis 1989) and the life cycle which is, however, not yet precisely known in all types. However, transitions and discrepancies were found also in polarity of hormogonia of several morphospecies (Kukk et al. 2001). Moreover, within the wide and variable genus *Scytonema* there are diverse clusters ("*Hofmanii*" type, "*Myochrotes*"type, etc.; Bourrelly 1985), the separation of which in different "small" genera according to molecular sequencing would be not surprising. The genus *Camptylonemopsis* has also features, which are "intermediate" in a certain degree between scytonematoid and tolypotrichoid character (Ghose 1920, Kumar 1962, Pandey 1965, Pandey & Mitra 1959, Bourrelly 1985). The hormogonia develop mainly isopolar, they grow apically at both ends, similarly as in *Scytonema*, but later the ends grow in slightly erect position, and sparse tolypotrichoid or scytonematoid branching can occur. However, just this type of development of thallus is specific in such a degree, that the genus is phenotypically well recognizable and can be accepted in taxonomic classification according to phenotype characters. The main diacritical features of heteropolar *Tolypothrix, Camptylonemopsis* and isopolar *Scytonema* are compared in Fig. 4, but to what degree are the mentioned characters stable needs further studies.

The Desikachary's (1948) diacritical feature of the genus *Camptylonemopsis,* presence of akinetes (or ability to form akinetes), is not commonly accepted, as the akinetes were not recognized in all later described species (Drouet 1973, Bourrelly 1985, and others). However, they almost do not occur in other *Scytonemataceae.* Pandey & Mitra (1959) and Pandey (1965) studied the life cycle of *Camptylonemopsis lahorensis* (which is the type-species of the genus *Camptylonemopsis* described originally from Pakistan) and came to the conclusion,

Table 1. – Diacritical phenotype characters of all described *Camptylonemopsis* species.

Species	W filament –center [μm]	W trichome –center [μm]	W trichome – ends [μm]	Sheaths	Constr.
C. semiaquatica Subrahmanyam 1973	1.9–3.5	1.6–3.2	slightly widened (acc. to figures)	thin, hyaline, lamellated	+
C. danilovii (Hollerbach) Desikachary 1948	3.3–3.7	2.8–3.3	3.3–3.7	thin, colourless	+
C. minor Desikachary 1948	3.9–7.9	2.6–5.2	slightly widened	thin, not lamellated, colourless	+ +
C. paperai Subrahmanyam 1973	4.5–7.0	3.8–5.8	± not widened	thick, lamellated	(+)
C. iyengari Desikachary 1948	5.2–6.6	(2.6) 3.9–5.2	slightly widened	thin, colourless, homogeneous	+
C. pulneyensis Desikachary 1948		(3.9) 5.2–9.3?	3.9–6.6 and widened	firm, thick, lamellated, colourless	+
C. *lahorensis* acc. to Pandey 1965	8–12	6–9	± not widened	thin to thick, lamellated and yellow-brown	(+) to ++ (under apex)
C. *lahorensis* (Ghose) Desikachary 1948		6–9	± not widened	inconspicuous, thin, later thick, lamellated and brownish	(+)
C. *dinghushanensis* Zhu 1987	14–16	6–10	trich. 3–5, fil. 8–12, ± inflated	firm, lamell., colourless to brownish, 5 μm wide	– or +
C. sennae spec. nova	13.3–17.8	8.6–12.5	± not widened	thin to thick,slightly lamell., yellow-brownish	–
C. epibryos spec. nova	15–16.5	11–14	not widened	thick, colourless, lamellated	–

that this species is only the "arrested stage" of *Tolypothrix arenophila* (originally described by W. et G. S. West 1897 from Angola; type material deposited in CU). The results of Pandey and Mitra do not prove that this genus should be included in the genus *Tolypothrix.* The term "arrested stage" is unclear and not well defined (dormant stages?), and we did not found any proof of the transient stages between *Camptylonemopsis*-type of thallus and typical *Tolypothrix* in papers available (including Pandey 1965) or in our material. The life cycle and thallus morphology described by Pandey (1965) is also specific, distinctly different from *Tolypothrix* and corresponds with our populations from Brazil (Fig. 4). The genus *Camptylonemopsis* differs from *Tolypothrix* by the basic isopolar structure of thallus, and from all other *Scytonemataceae* by the type of branching and by the life cycle (development of hormogonia, creeping and parallel arranged filaments).

The position of *Tolypothrix arenophila* within the genus *Tolypothrix* is unclear and it is possible, that this species in fact belongs also to *Camptylonemopsis.* However, no documentation of this species exists, and the original description, which has been repeatedly written in all manuals (compare Frémy 1930, Geitler 1932, Desikachary 1959, and others), does not provide a good solution. It is possible that *C. lahorensis* is really identical with *T. arenophila* sensu Pandey & Mitra (1959) and Pandey (1965), but there are distinct differences in comparison with original *T. arenophila,* especially in the width of filaments (8–12 against 14.5–15–18 μm) and in the morphology of filament ends. The later pre-

Cells l or w [µm]	Colour	Heterocytes [µm]	Akinetes [µm]	Ecology	Distribution
2.5–4		2–3 wide	–	subaerophytic, small pebbles moistened by rain water	Vijayawada, India
± 2.1–4.2	pale blue-green	2.1–3.3 × 2.8–3.3	–	subaerophytic, soils (cultures)	near Sankt Petersburg, Russia
3.9–9.2		3.9–6.6 lt, isodiam. to 2x longer > wide	5.2–10.5 × 3.9–6.6	epiphytic on C. pulneyensis in a pool	Kodaikanal, India
4.2–5.8		± spherical, 4.6–6.3	in rows, 4.3–5.9 × 3.9–5.5	moistened paper, waste	Vijayawada, India
5.2-10.5 × 2.6-5.2		–15.7 × 3.9-5.2-6.6	–	epiphytic on green algae	Vandalur, India
5.2–20.0	plant mass: light blue-green	7.9–19.6 × 5.2–10.5	–	among algae in pools	Kodaikanal, India
2–8 lg	pale blue-green	4–12 (18) × 8–18	–	soils	Allahabad, India
isodiam. or slightly lg. > lt.	mats bluish brown; cells bluish green	12–21 × 7–9	7–11 × 5–7	terrestrial	Lahore, Pakistan
8–10	blue-green	(3)10–12 × 5–7 (10)	–	epiphytic on Hepaticae, subaerophytic, bark of trees	Dinghushan, China
3.2–16.5	pale blue-green to pale-violet	6.8–15.4 × 10.2–11.2	–	subaerophytic, on rocks in streaming water	Paranapiacaba, Brazil
shorter than long	reddish violet	cylindrical, 8–14 lt., isod. or lg > lt	–	epiphytic on aquatic mosses	Ubatuba, Brazil

sented features of *C. lahorensis* (in sense of Pandey 1965) correspond better to the generic characters of the genus *Camptylonemopsis,* as described by Desikachary (1948, 1959), and as follow also from our studies. The localities of *Tolypothrix arenophila* are mainly from tropical biotopes (Africa – Angola and Natal: Frémy 1930; Pakistan – near Lahore: Desikachary1959). It is not clear, from where the locality "Ireland" appeared in several manuals (Frémy 1930, Geitler1932, etc.).

The problem remains, if the generic features of *Camptylonemopsis* are acceptable or not. It follows from our results, that the phenotype features justify the separation of the genus, but its confirmation by molecular methods is needed. It is possible to summarize, that the genus *Camptylonemopsis* differs phenotypically from the most related scytonematoid genera *Tolypothrix, Coleodesmium* and *Scytonema* by characteristical and unique life cycle (Fig. 4). The up to now described *Camptylonemopsis* species are reviewed in Table 1.

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Souhrn

Lesní formace, pokrývající pohoří na východním pobřeží Brazílie reprezentuje zvláštní typ humidního tropického pralesa („Mata Atlantica“) s četnými rostlinnými endemity. Je zvláště bohatá na epifytní floru včetně mikrofyt. Sinice (*Cyanoprokaryota, Cyanobacteria*) z této oblasti jsou téměř neznámé a obsahují mnoho specifických a unikátních rodů a druhů. Celá oblast je silně ohrožena a v poslední době byl zahájen její soustavný botanický průzkum. Z prvních výsledků studia sinic jsme vybrali pro tento článek charakteristiky dvou nových druhů rodu *Camptylonemopsis* (*C. epibryos* spec. nova, *C. sennae* spec. nova), který byl dosud znám pouze z tropů jižní a jihovýchodní Asie. V článku jsou diskutovány diakritické znaky a taxonomická charakteristika celého rodu, zejména jeho vztahy k příbuzným rodům *Coleodesmium, Tolypothrix* a *Scytonema*. K článku je připojen tabelární přehled všech druhů rodu *Camptylonemopsis*.

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