

## The distribution of the genus *Eucapsis* (Cyanobacteria, Synechococcales) in the western Carpathians

Rozšíření rodu *Eucapsis* (Cyanobacteria, Synechococcales) v západních Karpatech

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### Abstract

Representatives of the little known cyanobacterial coccoid genus *Eucapsis* Clements et Shantz have typical spherical cells, dividing regularly in three perpendicular planes in subsequent generations, and forming nearly regular microscopic cubic colonies. They are relatively rare, not forming large populations, but ecologically distinct (acidic, peaty habitats, plankton and benthos of waters). The genus contains about 30 various types, differing morphologically and ecologically, but with usually limited geographic distributions. In this article the main diacritical characters and ecology of eight *Eucapsis*-taxa from the western Carpathians in Slovakia are presented.

**Keywords:** coccoid Cyanoprokaryotes, *Eucapsis*, taxonomy, ecology, distribution, Slovakia, Poland

### Introduction

The genus *Eucapsis* Clements et Shantz (Merismopediaceae, Synechococcales) is a relatively little known and not very common coccoid cyanobacterial genus (Komárek & Anagnostidis 1998, Castenholz 2001). However, modern methodological evaluations by the polyphasic methods with combined molecular, morphological and ecological criteria substantially changed the taxonomic classification of cyanobacterial diversity. The diacritical characters of *Eucapsis* were also re-classified. It was recognized that several small-celled types of the genus, originally classified to *Chroococcus* Nägeli, belong to the cluster of *Eucapsis*-species (Komárková et al. 2010; cf. Castenholz 2001). This phylogenetic genus contains possibly 30 taxa on the species level, which can be characterized ecologically as well as by morphological markers. Several taxa occur in habitats of the western part of the Carpathian Mountains and are characteristic members of the Slovak cyanoprokaryotic microflora. Although they do not comprise a significant or dominant (mass) proportion of the plankton or benthos in water reservoirs and rivers or in the littoral of *Sphagnum*-bogs, their correct identification is important for classification of water ecosystems (cf. Komárek & Hindák 1989, Komárek & Anagnostidis 1998). Several species grow in special biotopes, such as peat

bogs, mineral springs (Hindáková et al. 2015) or in extreme habitats (Watanabe & Komárek 1994).

In this review all floristic data of eight species of this genus from various habitats in Slovakia are presented. However, after finishing of the modern taxonomic revision of the whole genus, this set of species will probably still be enlarged. The transfer of several small-celled taxa of the traditional genus *Chroococcus* to *Eucapsis* is particularly expected (Komárková-Legnerová & Cronberg 1994, Joosten 2006). It is interesting that the amorphous common mucilage in *Eucapsis* (in contrast to *Chroococcus*) is an important marker for the definition of both genera. Very important is also the position of thylakoids in cells (parietal vs. irregular) in both types.

### Material and methods

Plankton samples were collected by a plankton net (mesh size 10 µm) from the surface layer to a depth of 1.5 m, and directly from the *Sphagnum*-littoral of mountain lakes in 2012 and 2013. Observations were carried out under a Leitz Diaplan light microscope, and photomicrographs were taken with a Wild Photoautomat MPS45. The material was preserved in formaldehyde and are stored along with the micrographs at the Institute of Botany, the Academy of Sciences of the Czech Republic, Třeboň, and at the Institute of Botany, the Slovak Academy of Sciences, Bratislava.

### Results and discussion

The genus *Eucapsis* forms more or less one phylogenetic cluster (Komárková et al. 2010). Its morphological markers are spherical or slightly oval cells, organized in ± 3-dimensional, cubic microscopic colonies, enveloped by a colourless, mostly homogeneous slime and containing (1)2 to several cells. The cell division is regularly 3-dimensional (in three perpendicular planes in subsequent generations); this process causes the final cubic arrangement of cells. However, the arrangement can be also secondarily irregular in a majority of species. The cells are more or less spherical, grow to the original size before the next division and contain parietal (or slightly irregularly situated) thylakoids. It differs from the most related genus *Limnococcus* Komárková et al. by a slightly smaller size of cells, small differences in the arrangement of cells in colonies and by its position in the phylogenetic tree.

Eight species have been known in Slovakia, which can be recognized by diacritical characters, included in the following identification key (few species, mostly described under other generic names are not yet validly published; the corresponding manuscript with validation of such taxa will be published in the journal *Fottea* in 2016):

- 1a** Cells more than 5 µm in diameter ..... **2**  
**1b** Cells less than 5(6) µm in diameter ..... **3**  
**2a** Cells bright blue-green or olive green, in cubic colony mostly densely arranged, spherical to slightly elongate before division, (5)9–10(12) µm in diameter; mucilage thick, well visible; littoral of mountain lakes .....  
 ..... **1. *E. pseudoprescottii***

- 2b** Cells pale blue-green to greyish, in colonies slightly distant from one another, spherical, 5–6–(7.5)  $\mu\text{m}$  in diameter, mucilage delimited, well visible; littoral of mountain and lowland gravel-pit lakes ..... **2. *E. carpatica***
- 3a** Cells 2.4–6  $\mu\text{m}$  in diameter ..... **4**
- 3b** Cells smaller than 2.4  $\mu\text{m}$  in diameter ..... **5**
- 4a** Benthos of mountain lakes and pools ..... **3. *E. minor***
- 4b** Plankton and metaphyton of eutrophic lowland waters ..... **4. *E. densa***
- 5a** Species living in acidic swamps, moorland or peat-bogs, cells 1–2.4  $\mu\text{m}$  in diameter ..... **6. *E. starmachii***
- 5b** Species living in plankton, periphyton or metaphyton ..... **6**
- 6a** Cells 0.7–1  $\mu\text{m}$  in diameter ..... **7. *E. microscopica***
- 6b** Cells mostly bigger than 1  $\mu\text{m}$  in diameter ..... **7**
- 7a** Cells (1.4)1.8–2.3  $\mu\text{m}$  in diameter, pale blue-green. **5. *E. aphanocapsoides***
- 7b** Cells (1)3.4(6)  $\mu\text{m}$  in diameter, grey blue-green..... **8. *E. joostenii***

**1. *Eucapsis pseudoprescottii*** Komárek et Hindák (Figs 1, 2): Colonies small, (2)4–8(16) - celled. Cells spherical, more or less regularly, cubically arranged in colorless slime, (3.5)5–7.3(12)  $\mu\text{m}$  in diameter. Content more or less homogeneous, intensely blue-green.

Characteristic species for acidic swamps and peat bogs, stenotherm, occurring mainly in mountains. Probably distributed in the whole northern temperate zone. In Slovakia, it occurs sporadically in all corresponding mountainous areas. In the High Tatra Mts, we have found it in the littoral of Vyšné Rakytové pleso (in Komárek & Hindák 1989 under the name of *Eucapsis alpina*). This species was commonly identified as the Nordic *Eucapsis alpina* Clements et Shantz. However, this species forms very regular cubic, multicellular (with up to more than 120 cells) colonies. We did not find this type in Slovakia, but only populations corresponding to the "*Chroococcus prescottii* Drouet", which belong evidently in the genus *Eucapsis*, but with maximally 16 cells (a little larger than in *E. alpina*) and not forming perfectly cubic large colonies.

**2. *Eucapsis carpatica*** Komárek et Hindák (Figs 3, 4): Colonies usually with 8– to more than 20 cells, slightly distant from one another. Cubical arrangement clearly recognizable, but the cells are soon little shifted from their position. Cells pretty spherical, 5–6–(7.5)  $\mu\text{m}$  in diameter, with  $\pm$  homogeneous, pale greenish or grey-blue content.

Probably an endemic species of the western Carpathian Mountains, occurring in acidic mountainous peat bogs and raised bogs, but also in lowland gravel-pit lakes. The species was described from the Oravská Magura Mts (Komárek & Hindák 1989). Recently, we found it in the littoral of a small gravel pit lake at Rusovce in Bratislava (Hindáková & Hindák 2014), in the alkaline swamp Šujské rašelinisko (Hindáková & al. 2015) and in both the Slovak (Kobyliie pleso) as well as the Polish part (Staw Litworowy, Nad Stawem Wielkim) of the High Tatra Mts.

**3. *Eucapsis minor*** (Skuja) Elenkin: Colonies regular cubic, mostly large, compact, composed of subcolonies, 16–32–64– celled, with densely arranged cells and a hyaline mucilage layer. Cells spherical, widely oval or subspherical after division, 2.5–4 µm in diameter, bright blue-green in colour.

This species is similar to *E. alpine* (Komárek & Anagnostidis 1998) by having cubic colonies, but it differs by having smaller cells. In the High Tatra Mts, it was collected in several lakes and pools, usually in the alpine zone (Komárek & Hindák 1989).

**4. *Eucapsis densa*** Azevedo et al. (Fig. 5): Colonies compact, in principle with cubically and relatively densely arranged spherical cells, sometimes connected in larger agglomerations. Cells spherical, olive green or grey-blue-green, 2–6 µm in diameter with homogeneous or slightly granular content.

This species was described from Brazil, but it appears to be distributed over the whole subtropical and temperate regions of both hemispheres. It occurs sporadically in non-polluted swamps and backwaters, known from several localities. In Slovakia, it was found in the inundation zones of rivers.

**5. *Eucapsis aphanocapsoides*** (Skuja) Komárek et Hindák (syn.: *Chroococcus aphanocapsoides* Skuja) (Figs 6, 7): Colonies microscopic, more or less spherical or subspherical, with a colourless, homogeneous slime. Cells spherical, usually joined within colonies in ± cubic groups of 2–4(–8), with a slightly irregular arrangement, (1.4)1.8–2.3 µm in diameter, pale blue-green.

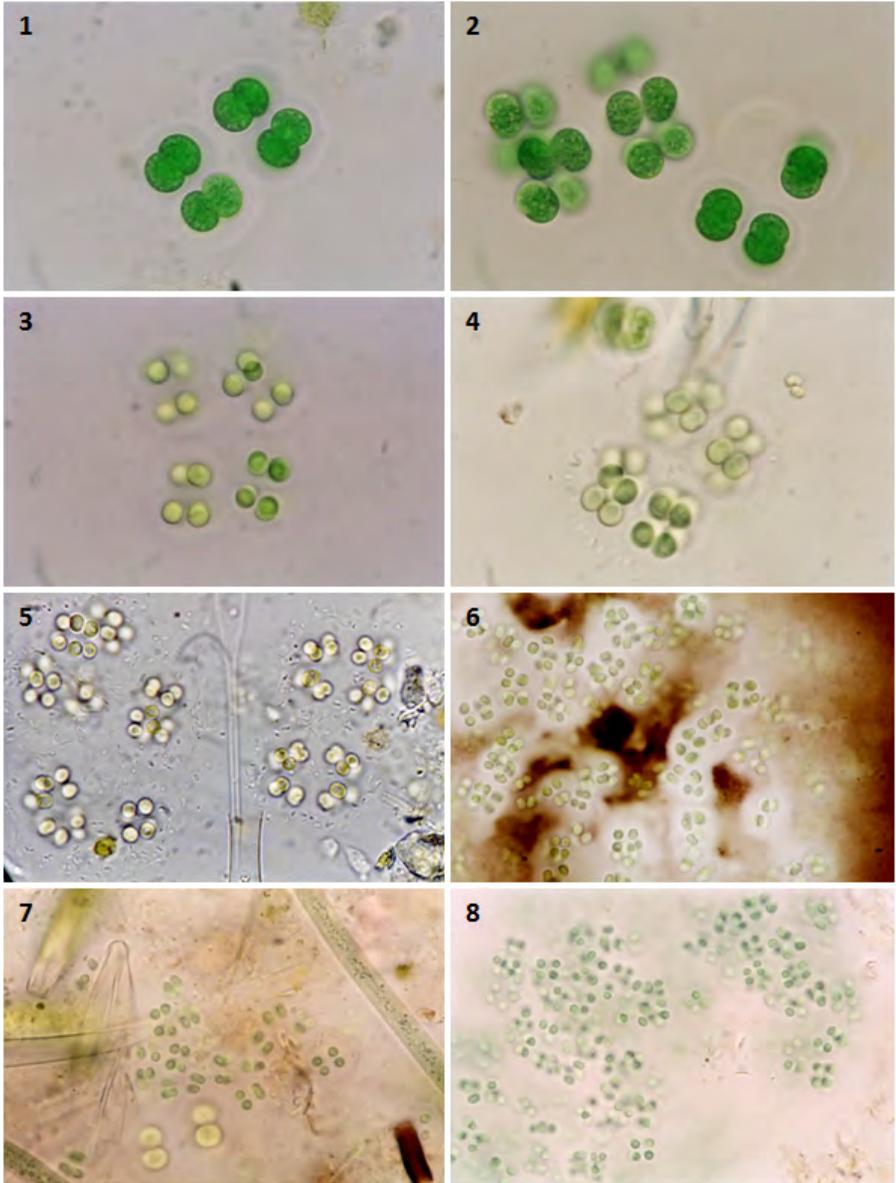
It occurs in the plankton of oligotrophic and mesotrophic lakes, with distribution from Svalbard and Scandinavia to central Europe, known also from Poland, the Netherlands (Joosten 2006) and Slovakia (Hindák 2008). The morphology of this species corresponds unambiguously to the genus *Eucapsis* in the present concept.

**6. *Eucapsis starmachii*** Komárek et Hindák (Fig. 8): Colonies small, with clearly separated, small, spherical cells, clearly distant one from another, with only an unclear cubic arrangement. Cells 1–2.4 µm in diameter, pale grey-green, with homogeneous content or with solitary granules.

In swamps and peat bogs, quite common, but not forming significant biomass. It is known only from mountains of Central Europe. We found it in the littoral of Kobylyie pleso in the High Tatra Mts.

**7. *Eucapsis microscopica*** (Komárková-Legnerová et Cronberg) Komárková (syn. *Chroococcus microscopicus* Komárková-Legnerová et Cronberg): Colonies microscopic, free-floating, with numerous very small cells, situated irregularly in an amorphous, colourless mucilage. Cells small, spherical or hemispherical (after division), 0.7–1 µm in diameter, pale greyish blue-green, after division unified in twos or 4(8)-celled cubes.

It occurs in the plankton of mesotrophic water reservoirs (or with increased salinity). It is found sporadically in lowland ponds and lakes in Slovakia. The position of this species in *Eucapsis* was confirmed by molecular sequencing.



Figs 1, 2 – *Eucapsis pseudoprescottii*, 3, 4 – *E. carpatica* (3 – Kobylyie pleso, 4 – Šujské rašelinisko), 5 – *E. densa*, 6, 7 – *E. aphanocapsoides*, 8 – *E. starmachii*.

**8. *Eucapsis joostenii*** Komárek et Hindák (*E. parallelepipedon* sensu Joosten 2006): Colonies microscopic, gelatinous with a colourless slime and cells freely (distant) cubically arranged. Cells spherical, 1–3.4(6) µm in diameter, grey blue-green.

It occurs in the plankton and periphyton of non-polluted pools and ponds, perhaps also in mountains areas, but not in high mountains. The original *E. parallelepipedon* is a tropical species. Specimens from the temperate zone (Europe) have slight morphological and ecological differences and belong evidently to a different genotype.

The complete review of the genus *Eucapsis* according to modern criteria is prepared for press (Komárek & Hindák). However, our short review should present the main types, mostly revised for the microflora of Slovak water ecosystems, as a basis for further research. This study is also a pilot introduction to the prepared study of the genus *Eucapsis*.

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### References

- AZEVEDO, M.T.P., SANT'ANNA, C.L., SENNA, P.A.C., KOMÁREK, J. & KOMÁRKOVÁ, J. 2003. Contribution to the microflora of chroococcalean cyanoprokaryotes in São Paulo State, Southeast Brazil. *Hoehnea* 20: 285-295.
- CASTENHOLZ, R.W. 2001. Phylum BX. Cyanobacteria, p. 473-599. In: BOONE D.R. & CASTENHOLZ R.W. (Eds), *Bergey's manual of systematic bacteriology*, Springer, New York.
- HINDÁK, F. 2008. *Colour Atlas of Cyanophytes*. Veda, Bratislava, 256 pp.
- HINDÁKOVÁ, A. & HINDÁK, F. 2014. Sinice a riasy malého štrkoviskového jazera v lesoparku v Rusovciach (záp. Slovensko) [Cyanobacteria and algae of a small gravel-pit pool in the park of Rusovce, Bratislava (Western Slovakia)]. *Bull. Slov. Bot. Spoločn.*, Bratislava 36(2): 145-153.
- HINDÁKOVÁ, A., HINDÁK, F. & BALÁŽOVÁ, T. 2015. Mikroflóra siníc a rias slatinného rašeliniska v Šuji v Rajeckej doline (stredné Slovensko) [Microflora of cyanobacteria and algae of an alkaline fen Šujské rašelinisko (Rajecká Valley, Central Slovakia)]. *Bull. Slov. Bot. Spoločn.*, Bratislava 37(1): 11-20.
- JOOSTEN, A.M.T. 2006. *Flora of the blue-green algae of the Netherlands I. The non-filamentous species of inland waters*. KNNV Publ., Utrecht, 239 pp.
- KOMÁREK, J. & ANAGNOSTIDIS, K. 1998. Cyanoprokaryota 1. Teil: Chroococcales. In: Ettl H., Gärtner G., Heynig H. & Mollenhauer D. (Eds), *Süßwasserflora von Mitteleuropa* 19/1, Gustav Fischer, Jena-Stuttgart-Lübeck-Ulm, pp. 548.
- KOMÁREK, J. & HINDÁK, F. 1989. The genus *Eucapsis* (Cyanophyta/Cyanobacteria) in Czechoslovakia. *Acta Hydrobiol.* 31: 25-34.
- KOMÁREK, J. & HINDÁK, F. Review of the cyanobacterial genus *Eucapsis* according to polyphasic approach. *Fottea* 16/1; in press.
- KOMÁRKOVÁ-LEGNEROVÁ, J. & CRONBERG, G. 1994. Planktic blue-green algae from lakes in South Scania, Sweden. Part I. Chroococcales. *Arch. Hydrobiol./Algolog. Stud.* 72: 13-5.

- KOMÁRKOVÁ, J., JEZBEROVÁ, J., KOMÁREK, O. & ZAPOMĚLOVÁ, E. 2010. Variability of *Chroococcus* (Cyanobacteria) morphospecies with regard to phylogenetic relationships. *Hydrobiologia* 639: 69-83.
- WATANABE, M. & KOMÁREK, J. 1994. Several Cyanoprokaryotes from Sagarmatha National Park, Nepal Himalayas. *Bull. Nat. Sci. Museum, Tokyo, Ser. B (Botany)*, 20/1: 1-31.

## Souhrn

Kokální cyanobakteriální rod *Eucapsis* Clements et Shantz tvoří mikroskopické kolonie obklopené bezbarvým slizem. Buňky jsou ± kulovité, bez plynových měchýřků v buňkách a dělí se téměř pravidelně ve třech na sebe kolmých rovinách v následných generacích. Tím často vznikají kolonie s buňkami sestavenými více méně do prostorového krychlovitého útvaru. Netvoří bohatě populace v našich obhospodařovaných vodách, jednotlivé druhy jsou však charakteristické pro vyhraněné ekosystémy, zejména v horských oblastech a v rašelinách. V tomto příspěvku uvádíme stručný přehled 8 druhů nalezených v oblasti Západních Karpat na Slovensku a determinační klíč k jejich identifikaci. Některé drobnější typy byly původně popsány v jiných rodech, zejména v rodě *Chroococcus*. V článku jsou akceptovány nejnovější nomenklatorické kombinace, připravené pro převod do rodu *Eucapsis* podle moderních analýz (Komárek & Hindák, v tlači).

## Zaujímavé cyanobaktérie a rozsievky v opustenom geotermálnom prameni v Kráľovej pri Senci na západnom Slovensku

Interesting phototrophic cyanobacteria and diatoms in water of an abandoned geothermal borehole at Kráľová near Senec (W Slovakia)

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### Abstract

In mineral water of an abandoned geothermal borehole (temp. 26.8 °C, pH 6.7) at Kráľová near Senec (W Slovakia) two main microscopic groups were recognized: cyanobacteria and diatoms. From coccoid cyanobacteria *Cyanobacterium* sp., *Chroococcus membraninus*, *Aphanocapsa thermalis* and *Aphanothece castagnei*, from trichal non-heterocyte types *Phormidium tergestinum*, *Ph. cf. griseo-violaceum*, *Geitlerinema acutissimum*, *G. cf. lemmermannii*, and *Spirulina subsalsa* were found. Most of the determined diatoms are common taxa, some prefer mineralised waters with higher calcium content, and can tolerate slightly polluted waters. The wide range of the morphological variability of frustules was observed by dominant taxa, e.g. *Navicula cf. veneta*, *Criticula cf. buderi*.

**Keywords:** phototrophic microorganisms, cyanoprokaryota, diatoms, thermal spring, W Slovakia