A multilocus phylogeny of the desmid genus *Micrasterias*:

Accelerated rate of morphological evolution in protists

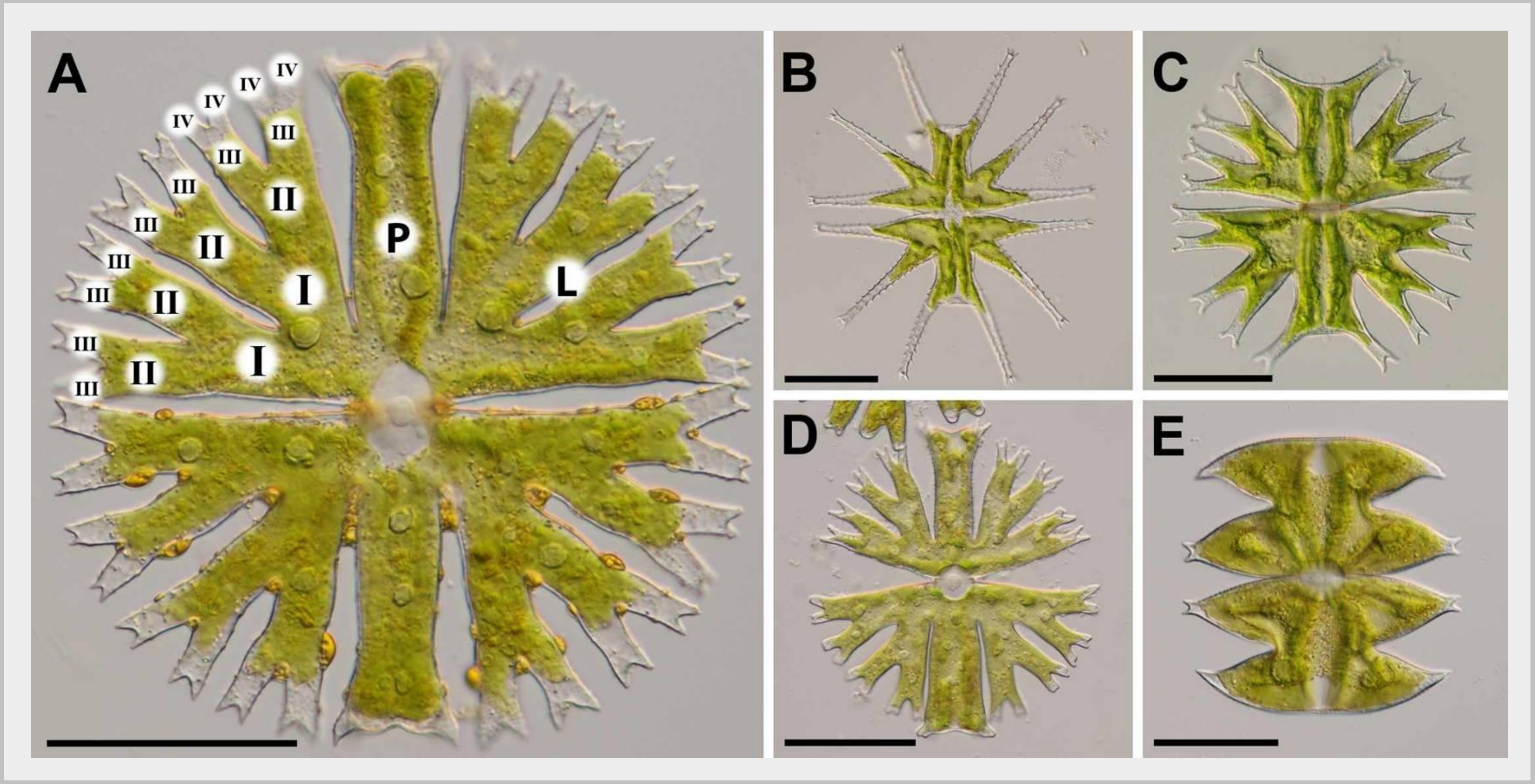
Pavel Škaloud, K. Nemjová, J. Veselá, K. Černá & J. Neustupa

Charles University in Prague, Czech Republic
CAUP Culture Collection of Algae

http://botany.natur.cuni.cz/algo

Micrasterias (Zygnematophyceae, Streptophyta)

- One of the most spectacularly shaped protists
- Flattened cells consisting of two identical, symmetrical semicells
- Species recognized by the overall shape, branching pattern, cell size, etc.



Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Aims

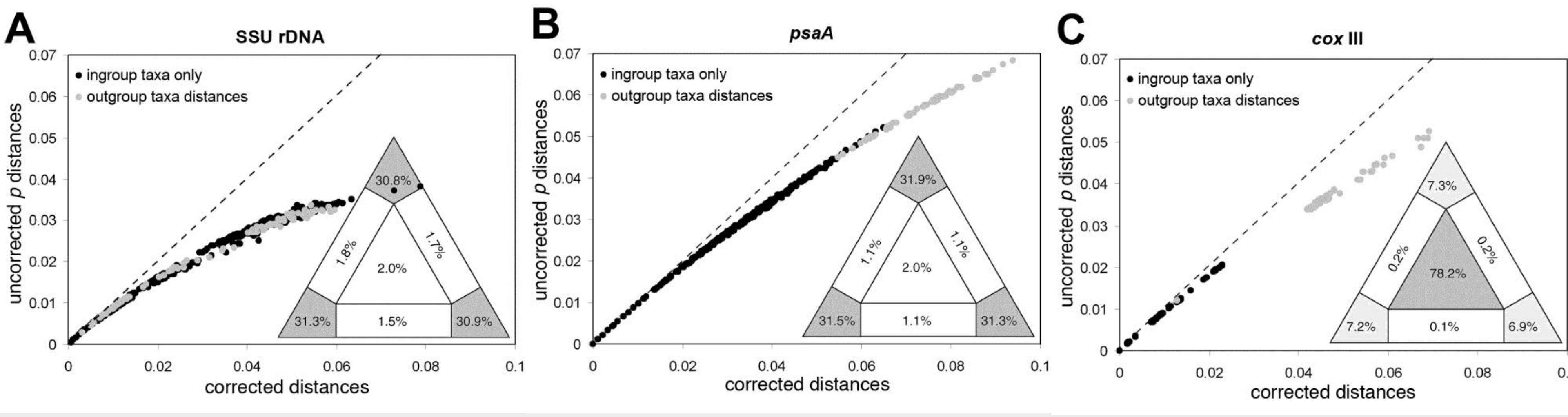
- ***Micrasterias* as a model organism to study the morphological evolution in protists**

- To infer the robust phylogeny of the genus
- To trace evolutionary phenotypic transformations leading to the existence of morphologically different but genetically related species
- To assess which morphological traits are correlated with the evolutionary structure of the genus
- To estimate possible biogeographic origins of the genus by tracing the distribution patterns of individual *Micrasterias* species

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

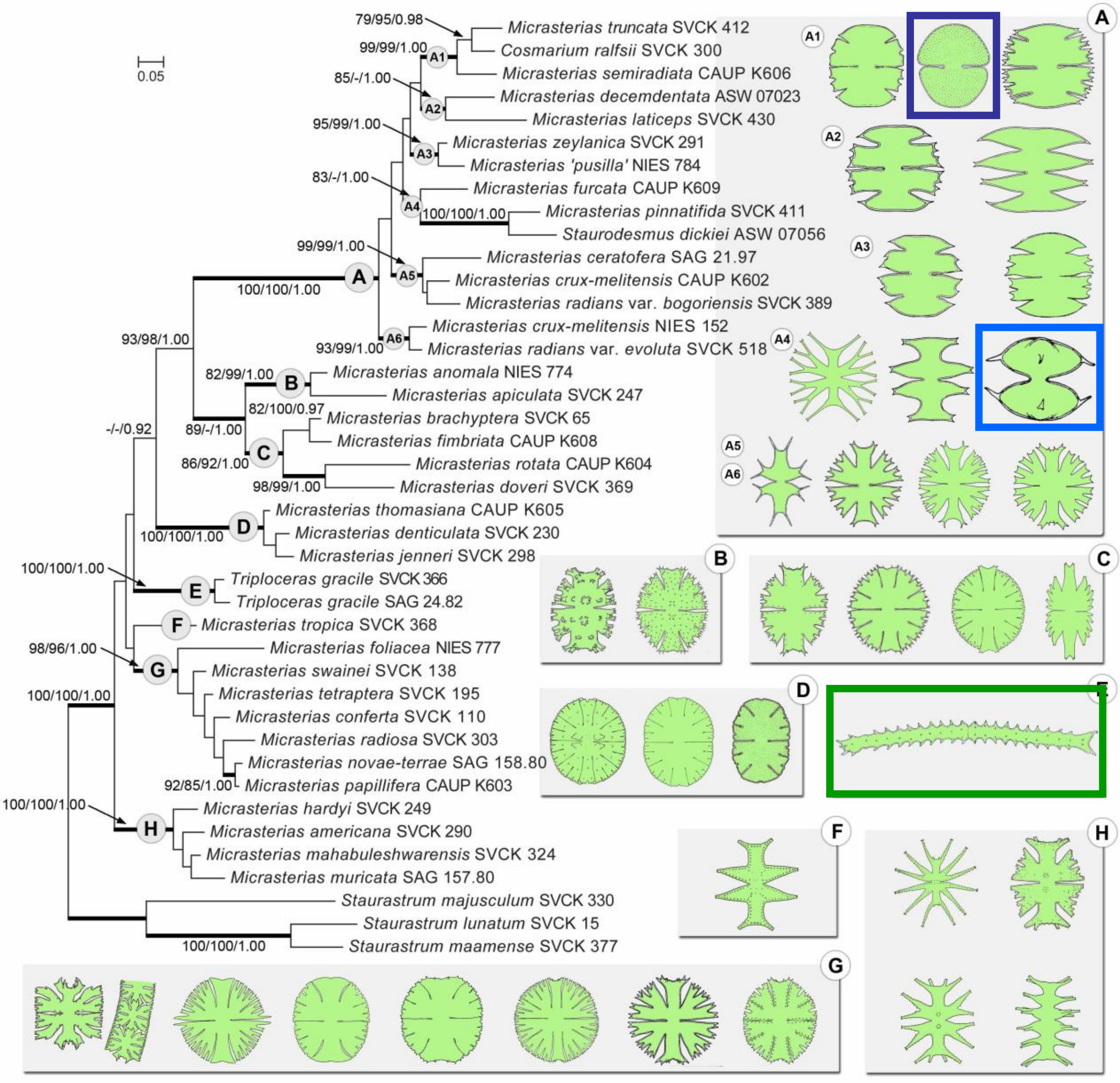
Molecular phylogeny

- Sequencing of SSU rDNA, *psa*A and *cox*III genes
- Significant saturation of SSU rDNA
- psaA dataset contained the highest amount of both variable and parsimony informative sites; best for differentiation *Micrasterias* from closely related genus *Staurastrum*



Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.* (in press)**

Molecular phylogeny



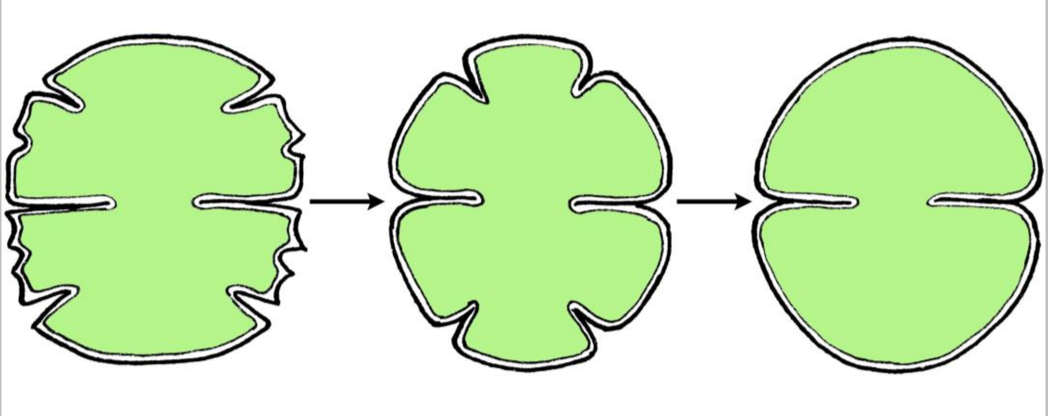
- Bayesian inference: single origin of the genus; 8 well-resolved lineages A-H
- Three species traditionally classified to different desmid genera were inferred within the genus *Micrasterias*:
  - ***Cosmarium ralfsii***
  - ***Staurodesmus dickiei***
  - ***Triploceras gracile***
- At least three periods of accelerated morphological evolution occurred during the diversification of the genus

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Accelerated morphological evolution I.

- *Micrasterias truncata* → *Cosmarium ralfsii*

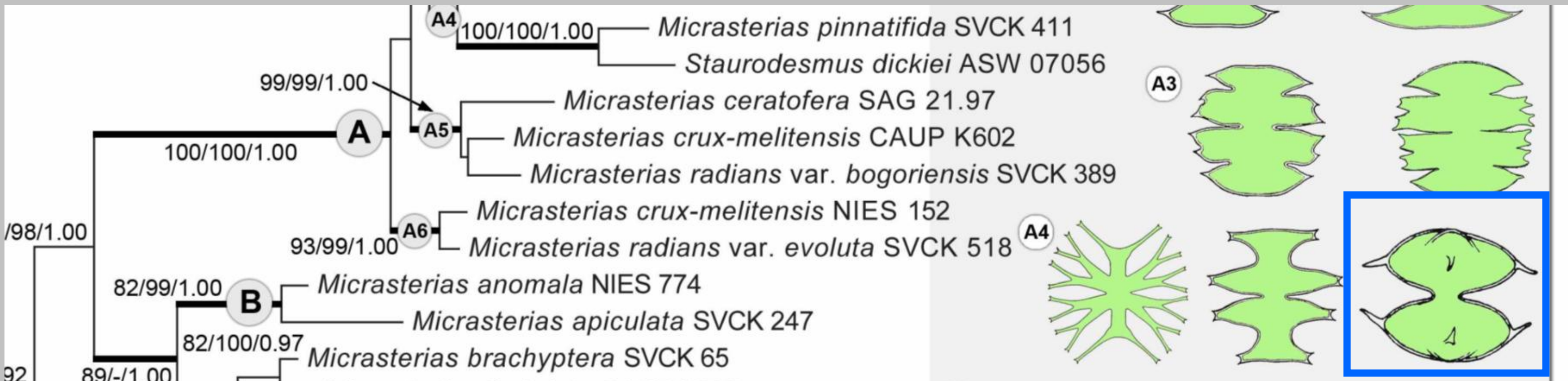
Evolutionary scenario - the successive reduction of lobe incisions, leading to the speciation into the smooth, unincised form typical for *Cosmarium ralfsii*



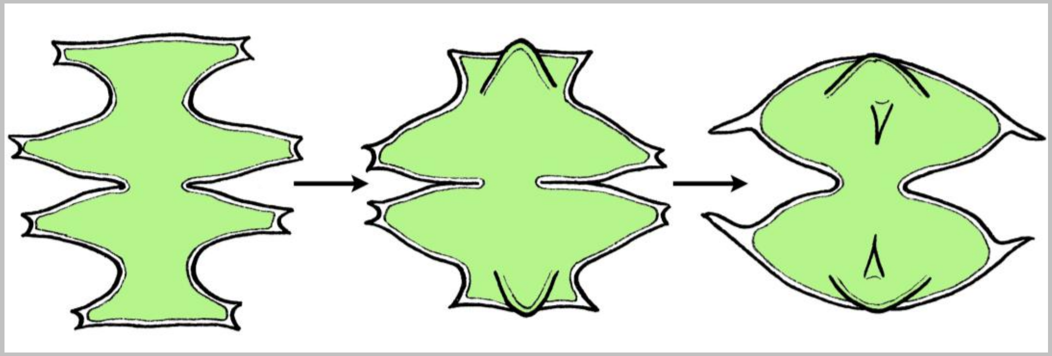
Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Accelerated morphological evolution II.

- *Micrasterias pinnatifida* → *Staurodesmus dickiei*



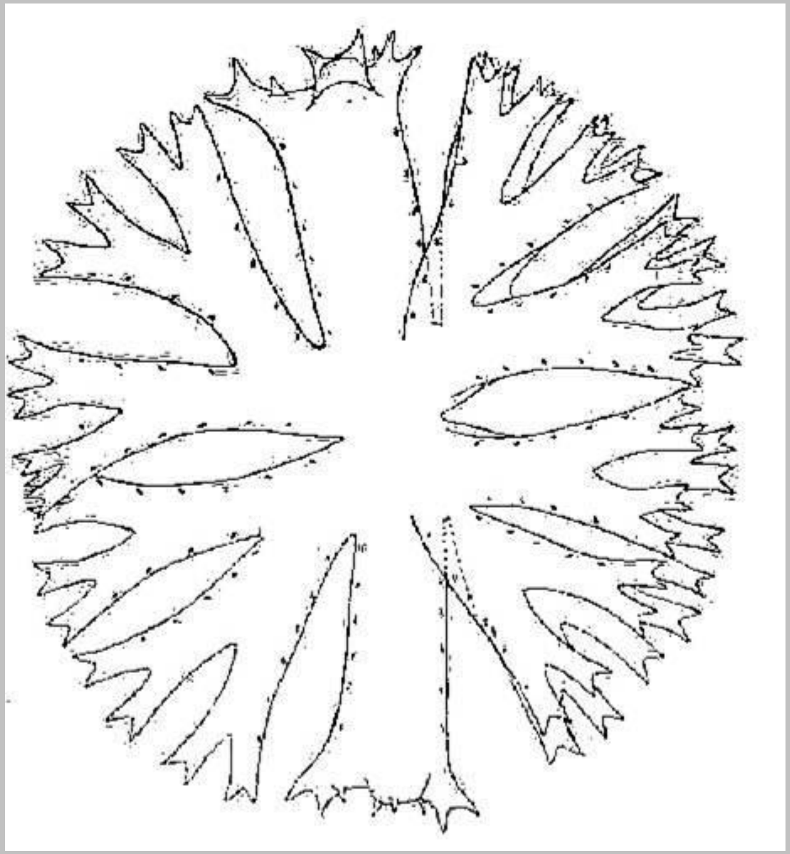
Evolutionary scenario - the natural polyploidisation of the *Micrasterias*-like ancestor, leading to the production of triradiate cells with reduced lobulation patterns

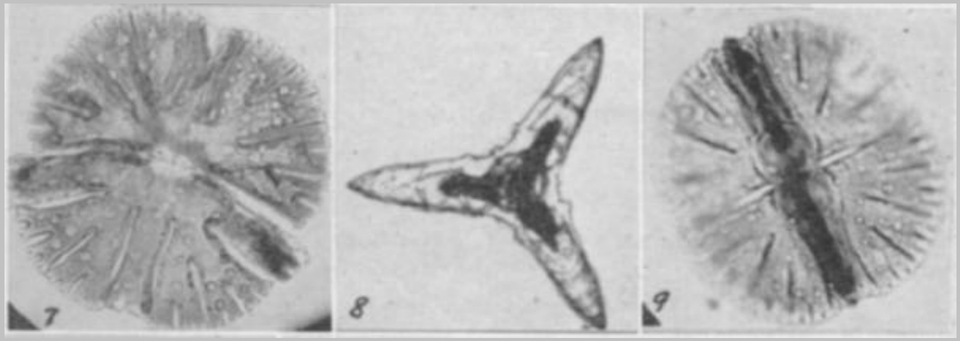


Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.* (in press)**

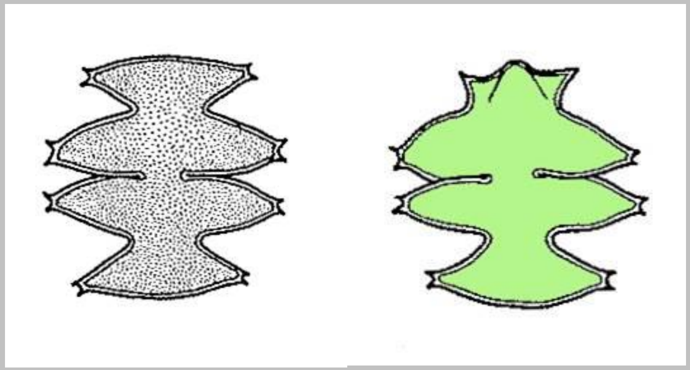
Accelerated morphological evolution II.

- The natural formation and artificial production of triradiate cells





- Kallio (1953): Bull Torrey Bot Club 80, 247-263; artificial production of triradiate *M. thomasiana* cells



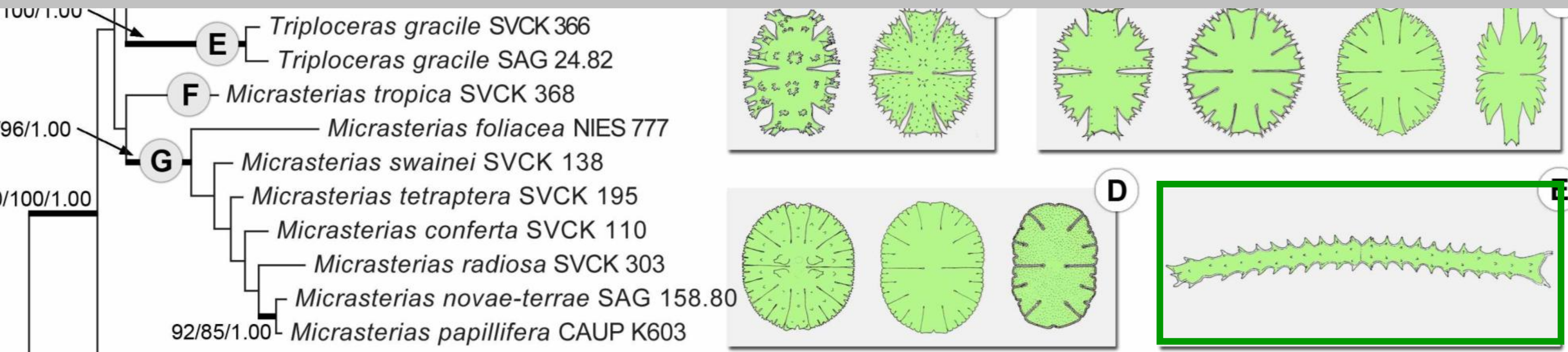
- West & West (1905): A monograph of the British Desmidiaceae; *M. murrayi* var. *triquetra*

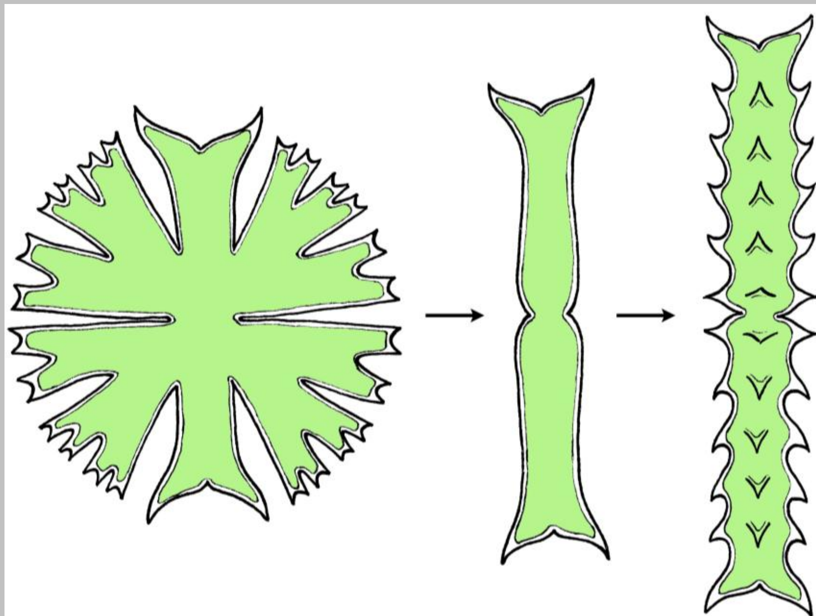
- Sormus *et al.* (1974): J Phycol 10, 274-279; *M. pinnatifida*

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Accelerated morphological evolution III.

- *Micrasterias* ancestor → *Triploceras gracile*





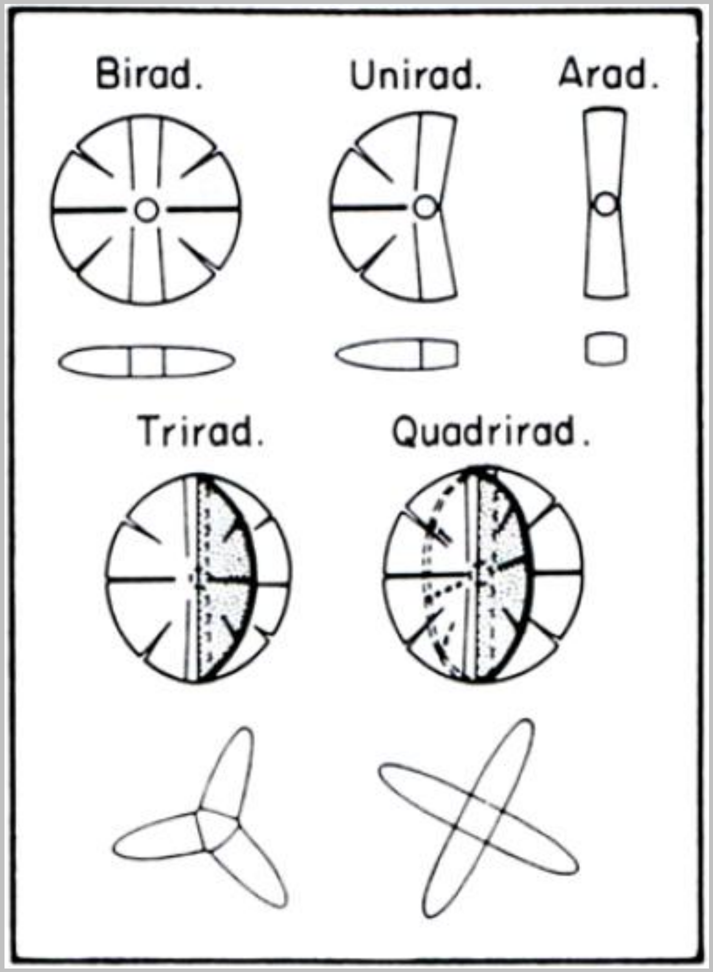
Evolutionary scenario - formation of aradiate cells, followed by the prolongation of polar lobes and creation of spiny mamillate protuberances on their surface

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Accelerated morphological evolution III.

- Formation of aradiate cells:

Kallio & Heikkilä (1969)
- artificial production of aradiate forms of *M. torreyi* by irradiation with ultraviolet light.

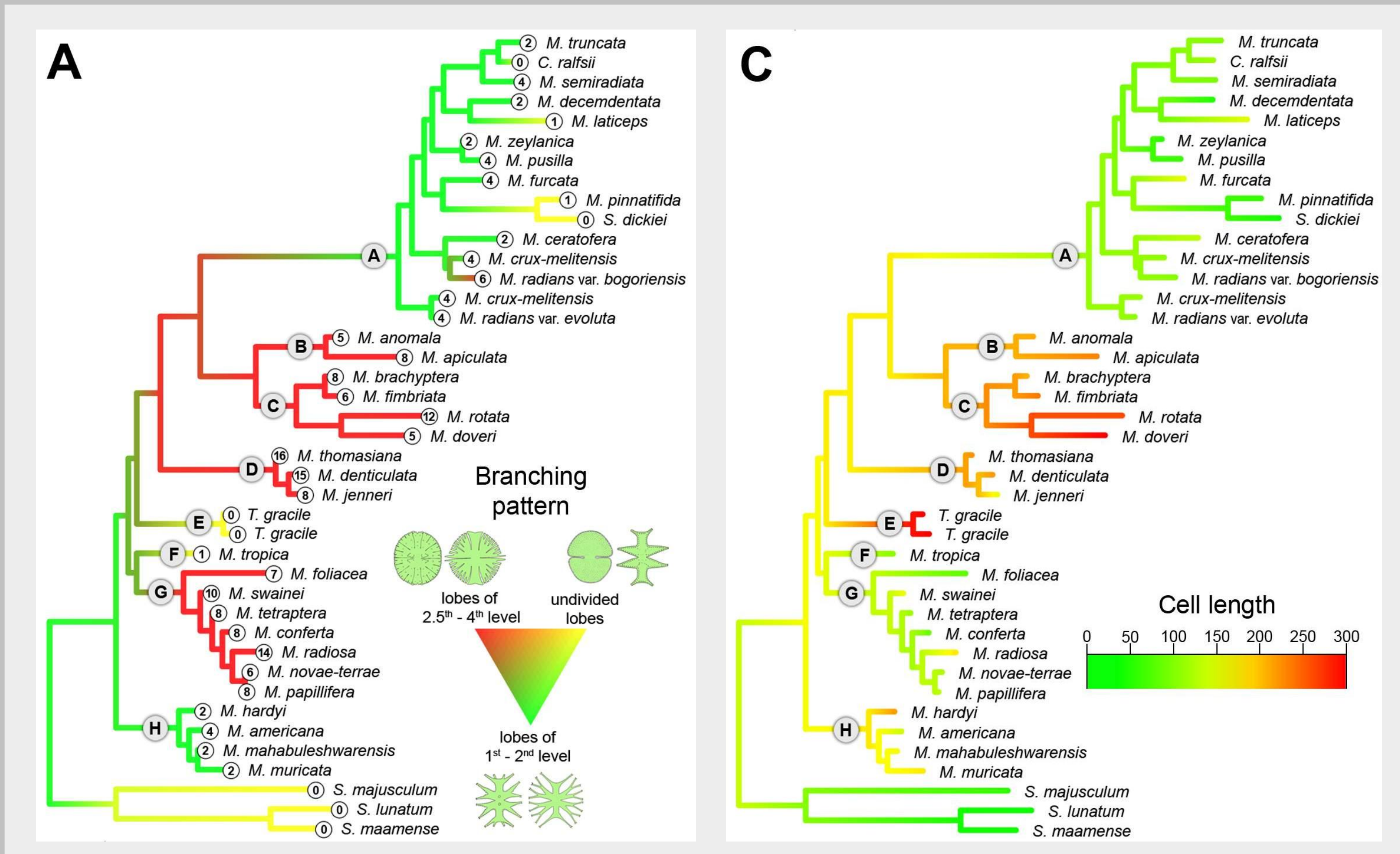


Waris & Kallio (1964)
- aradiate cells obtained from natural samples, suggesting that environmental disturbances causing formation of these forms may also occur in natural habitats.

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Evolution of morphological characters

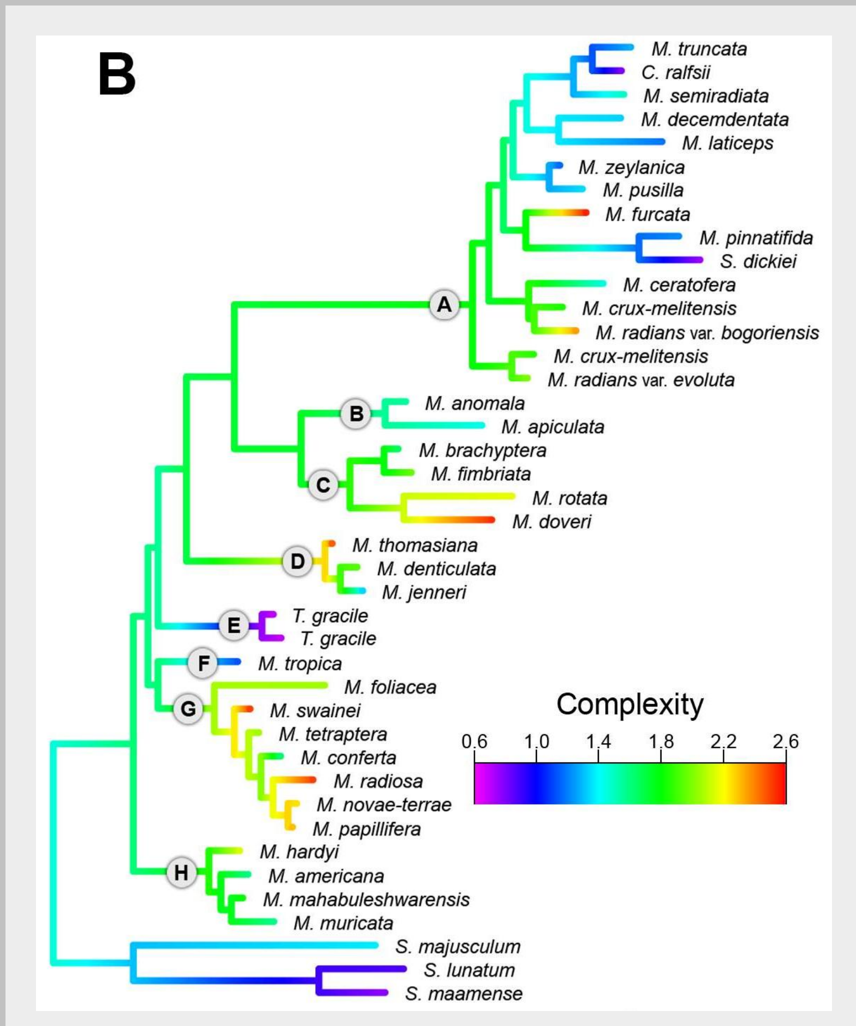
- Branching pattern and average cell length well correlate with the phylogeny



Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

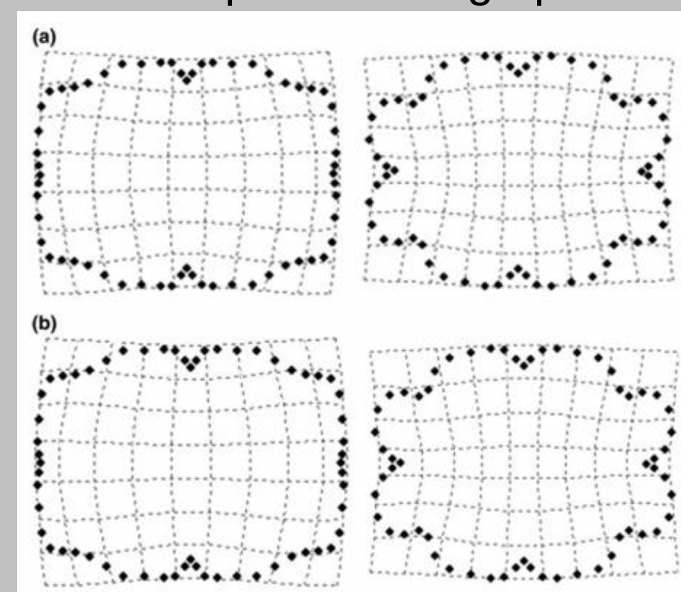
Evolution of morphological characters

- Cell complexity is uncorrelated with phylogenetic data



Černá & Neustupa (2010)
- the cell complexity may reflect adaptive morphological responses to external factors such as the pH level of the environment.

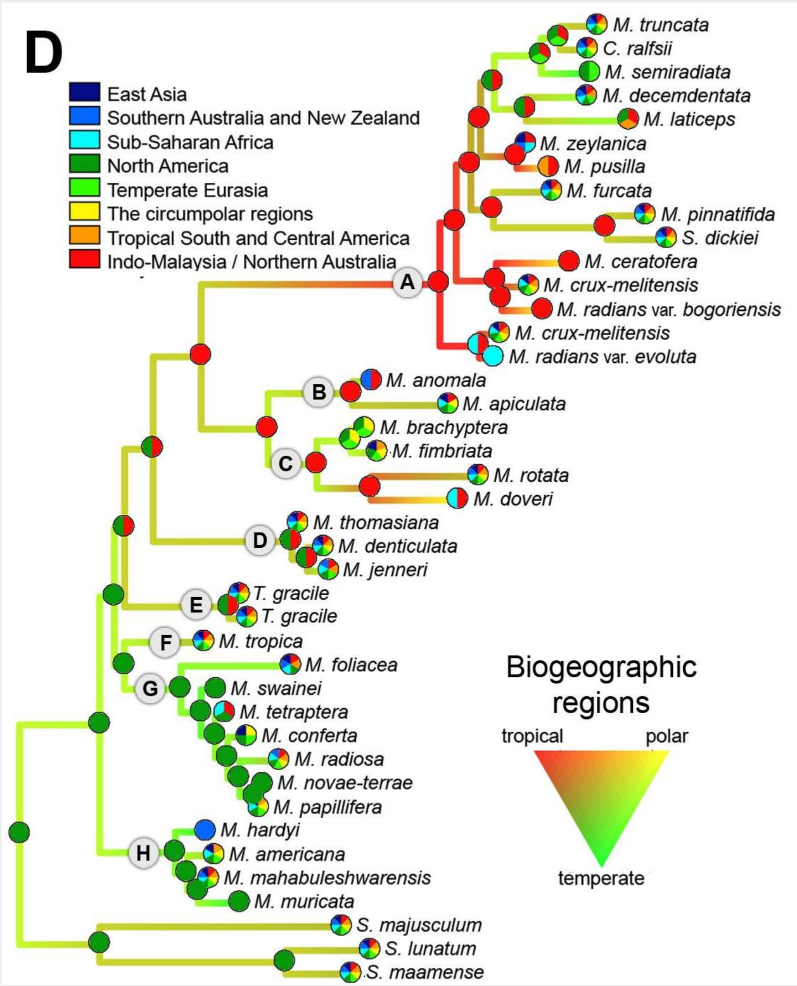
Low pH High pH



Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.* (in press)**

Biogeography

- The genus *Micrasterias* may have evolved in North America

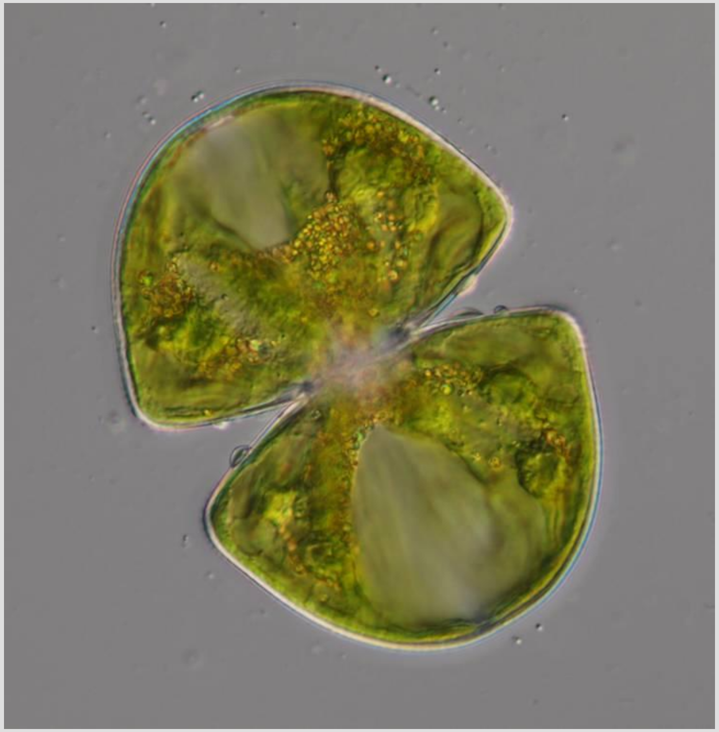


- Corroborated by the presence of rich desmid flora in North America and retention of species endemic to this region at the base of the phylogenetic tree.
- Ancient members of the genus might then subsequently migrate to other geographical regions including the tropics.

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Taxonomic consequences

- Formal transfer of *Cosmarium ralfsii* and *Staurodesmus dickiei* into the genus *Micrasterias*

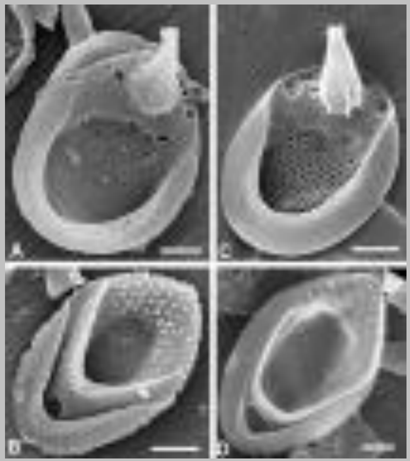


Micrasterias ralfsii

Micrasterias dickiei

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Conclusions



- Morphology of desmid species could abruptly change during a relatively short period of its evolution. Such evolutionary patterns would be inconsistent with the theory of a long-term morphological stasis of protist species raised by Fenchel and Finlay (2006), Martín-Gonzáles et al. (2008) or Siver & Wolfe (2005).

- Along with ultraviolet light and cold shocks, rapid morphological changes of desmid populations could be induced by natural polyploidisation.

Art	Stamm	Herkunft	Chromosomen-zahl	Abb.
M. americana	M 116	?*	ca. 205 [2]	6a, b
	M 139	U.S.A.	ca. 135 [1]	7a, b
	K 1483	U.S.A.	93 (91–95) [1]	8a, b
M. americana var. *boldtii*	M 114	Finnland	88 (86–90)	9a, b
M. americana var. *westii*	M 76	Finnland	135 (134–136)	10a, b
M. brachyptera	M 65	Finnland	98 [2]	11a, b
M. conferta	M 110	Finnland	39	12a, b
M. crux-melitensis	M 72	Finnland	ca. 110	–
	M 98	Finnland	110 (107–113)	13a, b
	M 128		ca. 100	

Kasprik (1973): Beih. Nova Hedwigia 42: 115-137.

Škaloud P. et al.: A multilocus phylogeny of the desmid genus *Micrasterias* (Streptophyta): evidence for the accelerated rate of morphological evolution in protists. ***Mol. Phyl. Evol.*** **(in press)**

Acknowledgements

- We are greatly indebted to Monika Engels (SVCK culture collection), Maike Lorenz (SAG culture collection), Fumie Kasai (NIES culture collection), Barbara Melkonian (CCAC culture collection) and Jerry Brand (UTEX culture collection) for kind provision of a number of strains used in this study.

- The study has been supported by the grant no. 206/09/0906 of the Czech Science Foundation.