

Photobiont switch and cephalodia emancipation as evolutionary drivers in the lichen symbiosis

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Introduction

Lichen symbioses in the order Peltigerales are formed by the association of an ascomycete mycobiont with either a cyanobacterial photobiont (**bipartite thalli**) or both a cyanobacterial and a green algal photobiont (**tripartite thalli**, in this case cyanobacteria are located in structures called **cephalodia**).

Bipartite thalli can be either **pannarioid** (photobiont restricted to a thin layer within the thallus) or **collematoid** (photobiont spread all over the thallus and gelatinous when wet).

Traditionally, collematoid thalli were mostly referred to the family Collemataceae, and all tripartite Pannariaceae were part of the genus *Psoroma*. Molecular studies have recently shown that several genera with collematoid thalli belong to the Pannariaceae, and that tripartite thalli don't form a monophyletic group inside Pannariaceae.

Aims

- Assess the phylogenetical position and relationships of the tripartite and collematoid thalli in the family Pannariaceae
- Test the hypothesis that switch of photobiont plays a crucial role in such variations
- Evaluate the evolutionary patterns and drivers involved.

Results and discussion

- Comparison of the phylogenies of both partners suggests frequent switches from pannarioid to collematoid thalli, strongly correlated with photobiont switches, as well as several shifts from tripartite to bipartite thalli.

- Ancestors of several groups appear to be tripartite thalli, bipartite thalli being the result of cephalodia emancipation from tripartite thalli; free-living cephalodia can eventually evolve and form distinct lineages, as suggested by the presence of the same *Nostoc* phylotype in *Physma* and a closely related tripartite thallus.

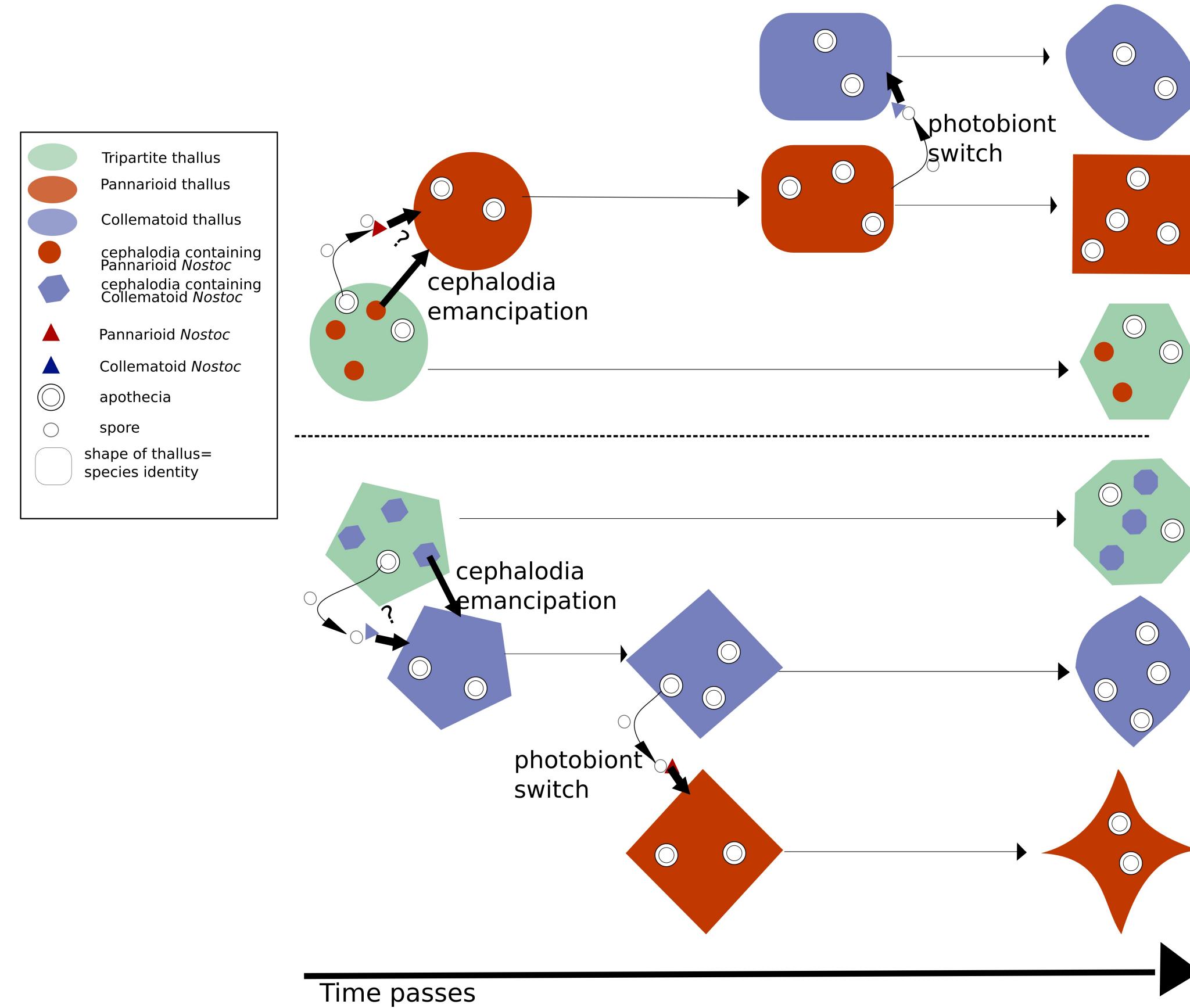
- *Nostoc* switch can result in a change of the morphology of the thallus, as for the genera *Fuscopannaria* (pannarioid thallus) and *Kroswia* (collematoid thallus): the latter is nested within *Fuscopannaria*, but is associated with a very different *Nostoc* photobiont.

- *Nostoc* from collematoid thalli are related to *Nostoc* from Collemataceae, and never associated with pannarioid thalli ; these thalli associate with *Nostoc* phylotypes that are otherwise lichenized with genera from other families, of similar morphology.

- We suggest a pattern where cephalodia emancipation and photobiont switches are drivers for divergence and speciation.

- Photobiont switch is assumed to be recent when little divergence is detected between both thallus types such as in the *Fuscopannaria*/*Kroswia* example.

A more ancient origin is suspected for the changes in the clade formed by tripartite "Pannaria" (R969), *Parmeliella borbonica*, *Physma* and *Elvebakkia* (= the *Parmeliella mariana* gr.); two events of cephalodia emancipation or a single event of cephalodia emancipation followed by a photobiont switch are the most likely scenarios.



Material and Methods

- Freshly collected representatives of the Pannariaceae from Reunion Island, Madagascar and Thailand.
- 4 loci (5.8S, LSU, RPB1 and mtSSU) for the fungus.
- 1 locus (16S) for *Nostoc*.
- Phylogenetic analyses: RAxML-HPC, MrBayes.
- Reconstruction of ancestral characters: SIMMAP, Mesquite and BayesTraits.

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