Endosymbiosis and kleptoplasty in the evolution of complex algae

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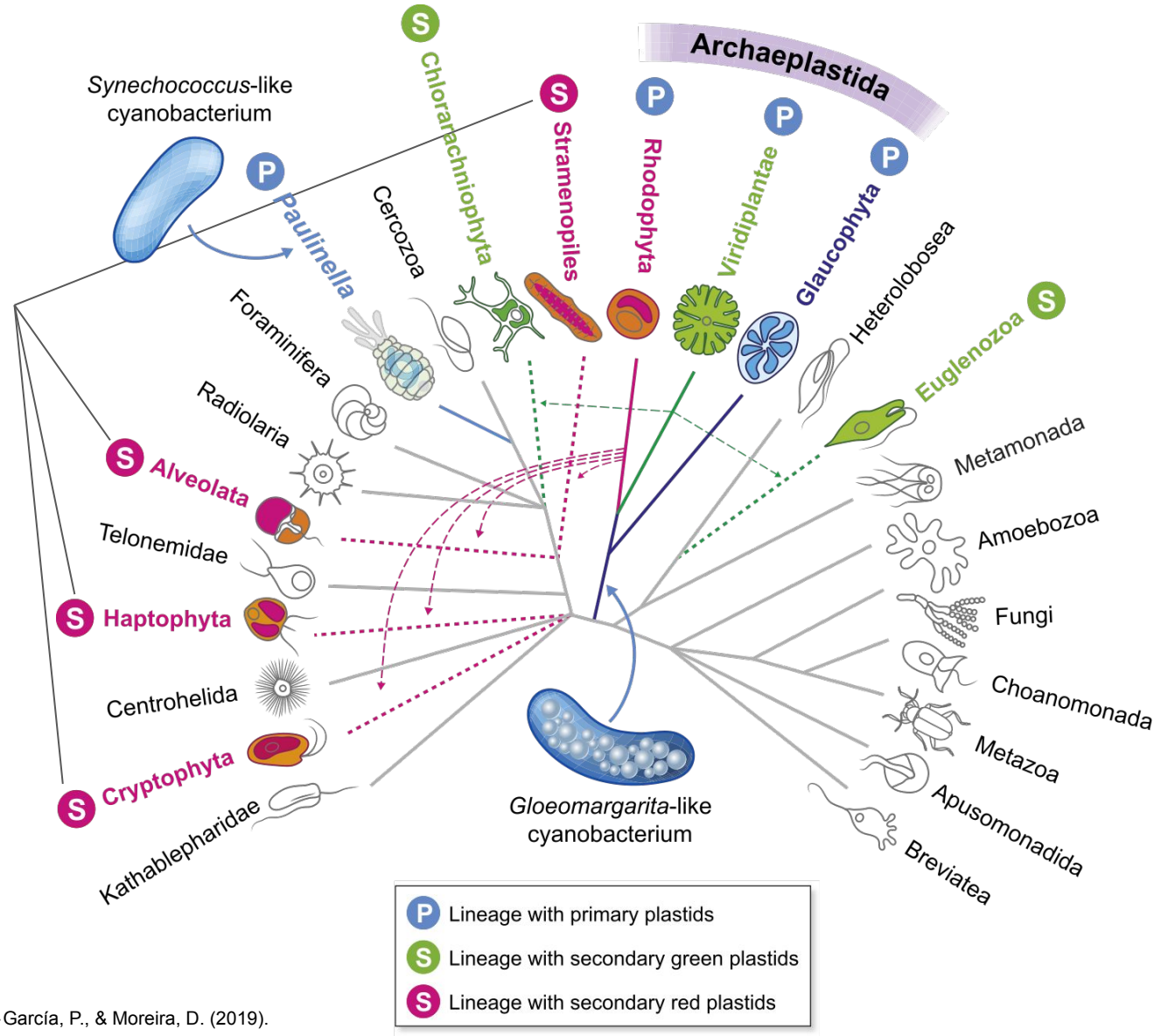
AMPEE7
Tuesday, 14th November
Liège, Belgium

Ciccarelli et al., 2006

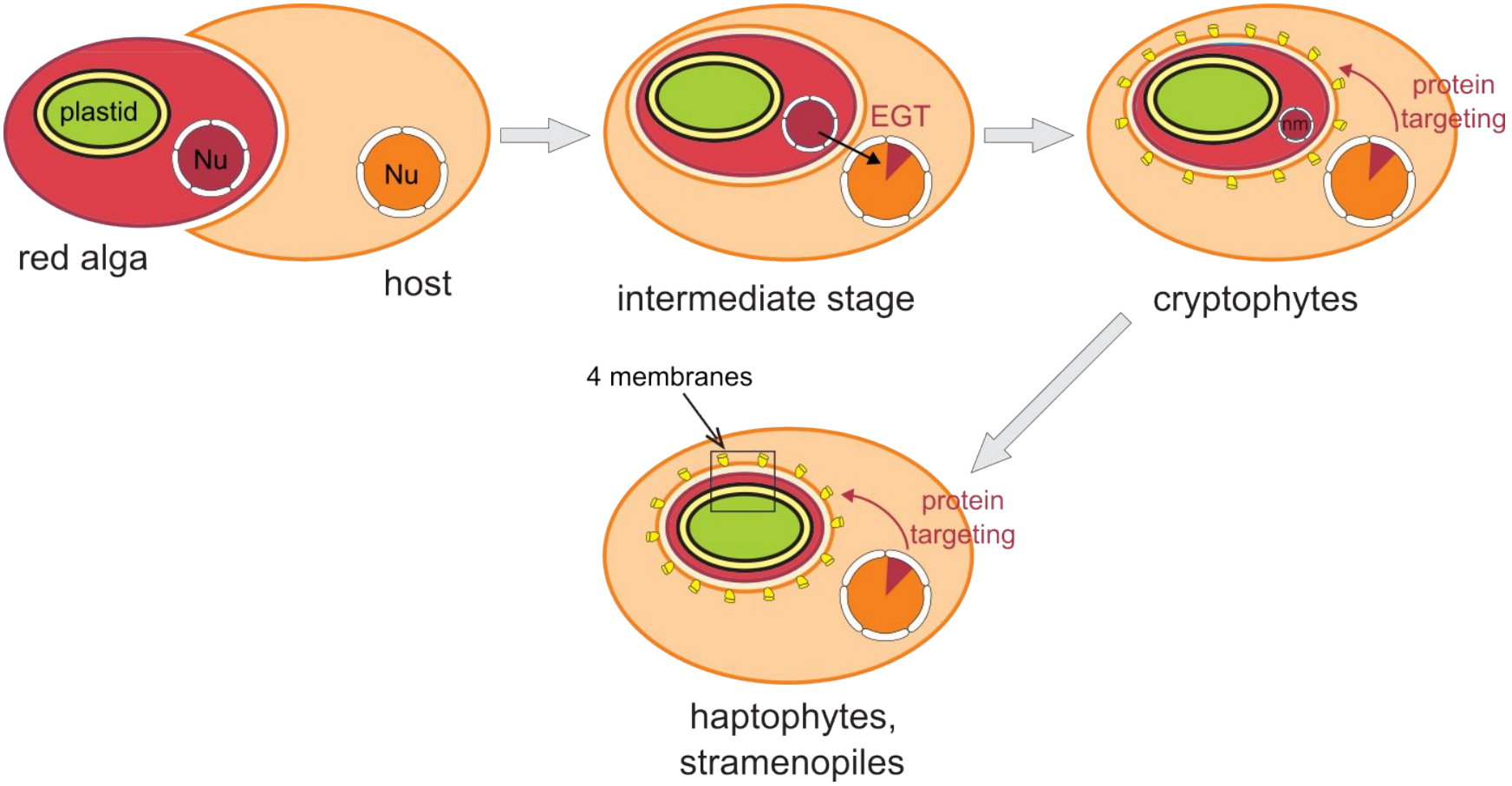
Complex Algae - Panorama

CASH lineages



Ponce-Toledo, R. I., López-García, P., & Moreira, D. (2019).

Endosymbiosis/Single source EGT



Adapted from Bodył A, Mackiewicz P, Stiller JW. BioEssays. 2009;31:1219–32.

Gene mosaicism

REPORTS

Genomic Footprints of a Cryptic Plastid Endosymbiosis in Diatoms

Ahmed Moustafa,[1]* Bánk Beszteri,[2]* Uwe G. Maier,[3] Chris Bowler,[4,5] Klaus Valentin,[2] Debashish Bhattacharya[1,6]†

ARTICLE

OPEN
doi:10.1038/nature11681

Algal genomes reveal evolutionary mosaicism and the fate of nucleomorphs

Bruce A. Curtis[1,2,3], Goro Tanifuji[1,2,3], Fabien Burki[3,4], Ansgar Gruber[5]†, Manuel Irimia[6], Shinichiro Maruyama[1,2,3], Maria C. Arias[7], Steven G. Ball[7], Gillian H. Gile[1,2,3], Yoshihisa Hirakawa[3,4], Julia F. Hopkins[1,2,3], Alan Kuo[8], Stefan A. Rensing[9]†, Jeremy Schmutz[8,10], Aikaterini Symeonidi[9], Marek Elias[11], Robert J. M. Eveleigh[1,2,12], Emily K. Herman[13], Mary J. Klute[13], Takuro Nakayama[1,2,3], Miroslav Obornik[14,15,16], Adrian Reyes-Prieto[3,17], E. Virginia Armbrust[18], Stephen J. Aves[19], Robert G. Beiko[20], Pedro Coutinho[21], Joel B. Dacks[13], Dion G. Durnford[17], Naomi M. Fast[4], Beverley R. Green[4], Cameron J. Grisdale[4], Franziska Hempel[22], Bernard Henrissat[21], Marc P. Höppner[23], Ken-Ichiro Ishida[24], Eunsoo Kim[25], Luděk Kořený[14,15], Peter G. Kroth[5], Yuan Liu[19,26], Shehre-Banoo Malik[1,2,3], Uwe G. Maier[22], Darcy McRose[27], Thomas Mock[28], Jonathan A. D. Neilson[17], Naoko T. Onodera[1,2,3], Anthony M. Poole[29], Ellen J. Pritham[30], Thomas A. Richards[26], Gabrielle Rocap[18], Scott W. Roy[31], Chihiro Sarai[24], Sarah Schaack[32], Shu Shirato[24], Claudio H. Slamovits[1,2,3], David F. Spencer[1,2,3], Shigekatsu Suzuki[24], Alexandra Z. Worden[27], Stefan Zauner[22], Kerrie Barry[8], Callum Bell[33], Arvind K. Bharti[33], John A. Crow[33], Jane Grimwood[8,10], Robin Kramer[33], Erika Lindquist[8], Susan Lucas[8], Asaf Salamov[8], Geoffrey I. McFadden[34], Christopher E. Lane[1,2,3,35], Patrick J. Keeling[3,4], Michael W. Gray[1,2,3], Igor V. Grigoriev[8] & John M. Archibald[1,2,3]

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RESEARCH ARTICLE

Chimeric origins of ochrophytes and haptophytes revealed through an ancient plastid proteome

Richard G Dorrell[1]*, Gillian Gile[2], Giselle McCallum[1], Raphaël Méheust[3], Eric P Bapteste[3], Christen M Klinger[4], Loraine Brillet-Guéguen[5], Katalina D Freeman[2], Daniel J Richter[6,7], Chris Bowler[1]*

PNAS

RESEARCH ARTICLE | EVOLUTION

OPEN ACCESS

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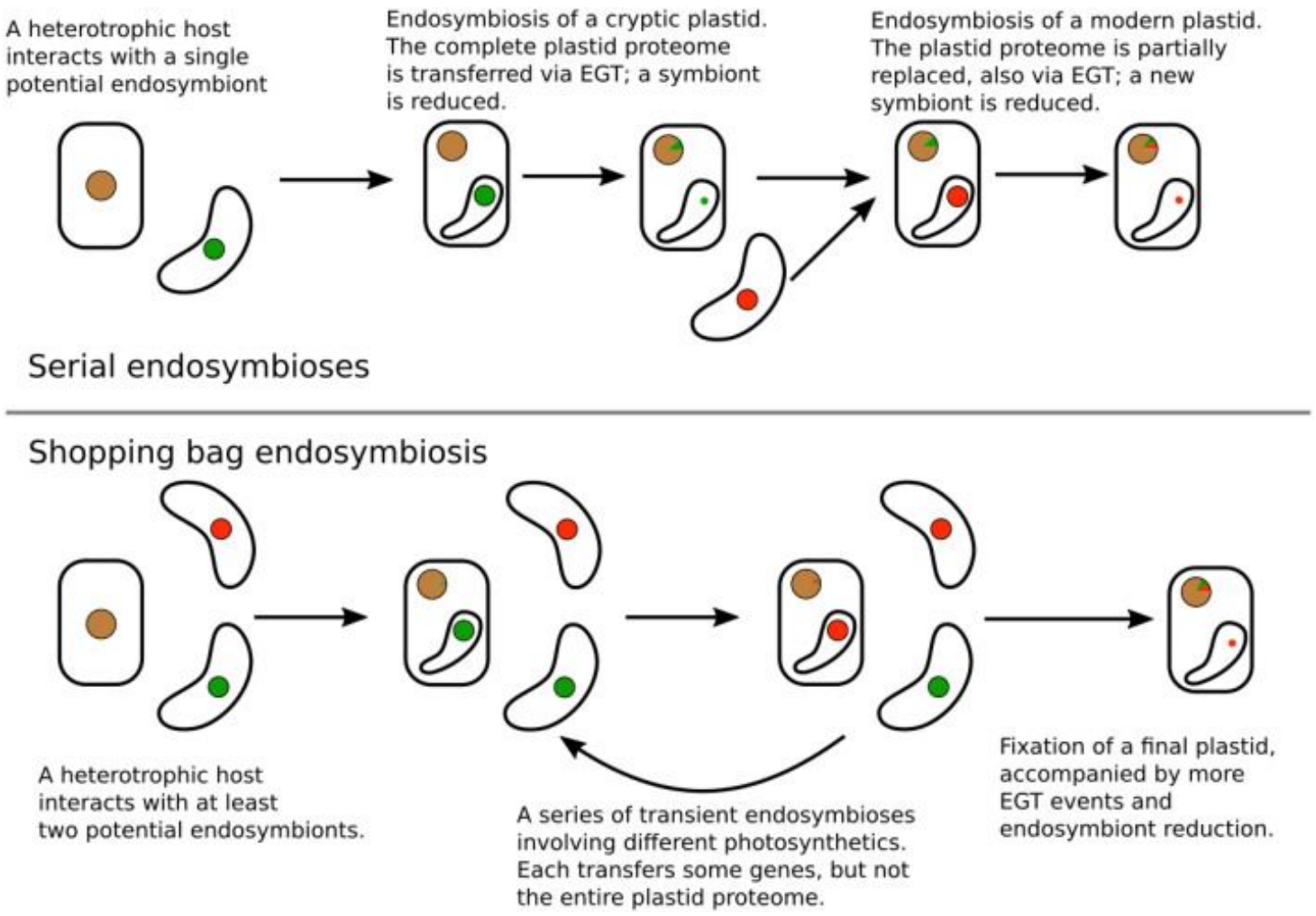
Euglenozoan kleptoplasty illuminates the early evolution of photoendosymbiosis

Anna Karnkowska[a,b,c,1,2], Naoji Yubuki[a,b,1], Moe Maruyama[d,e,1], Aika Yamaguchi[f], Yuichiro Kashiyama[d,e,2], Toshinobu Suzaki[g], Patrick J. Keeling[a], Vladimír Hampl[b], and Brian S. Leander[a,h,2]

Edited by Edward DeLong, University of Hawai'i at Manoa, Honolulu, HI; received November 30, 2022; accepted February 14, 2023

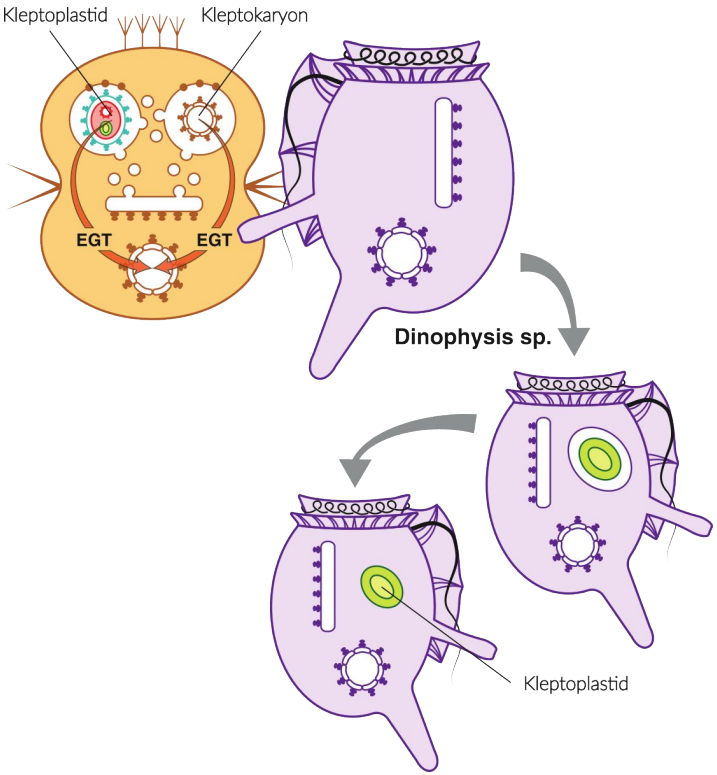
MODELS



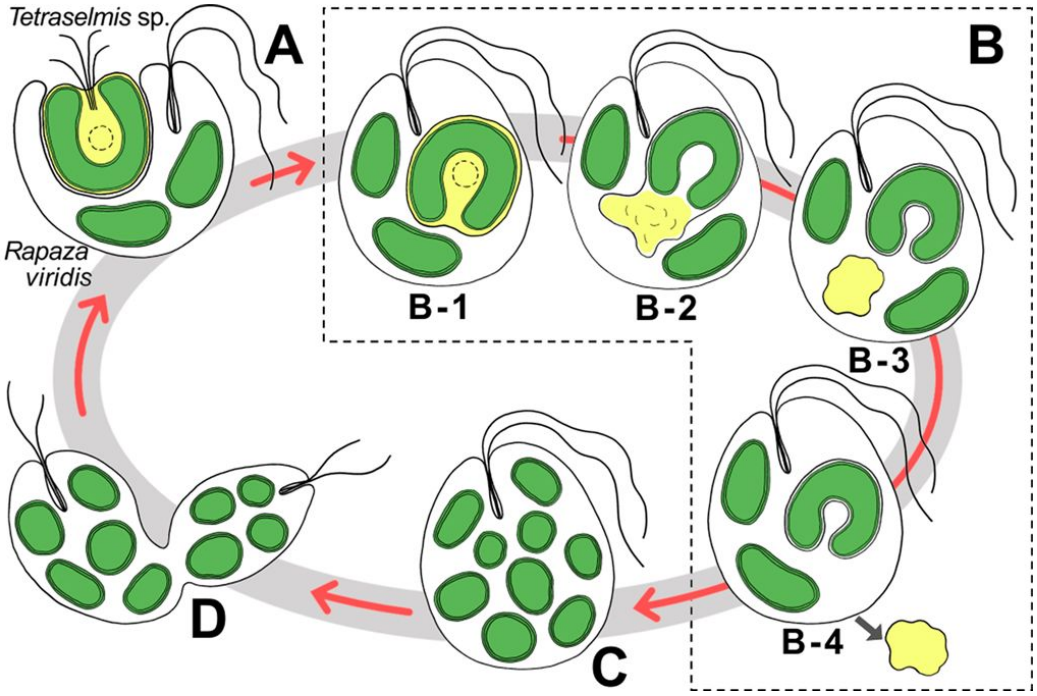
MorozovA.A.GalachyantsYuri P 2019.

“Shopping bag” by kleptoplasty

Kleptoplasty by myzocytosis



Kleptoplasty by phagocytosis

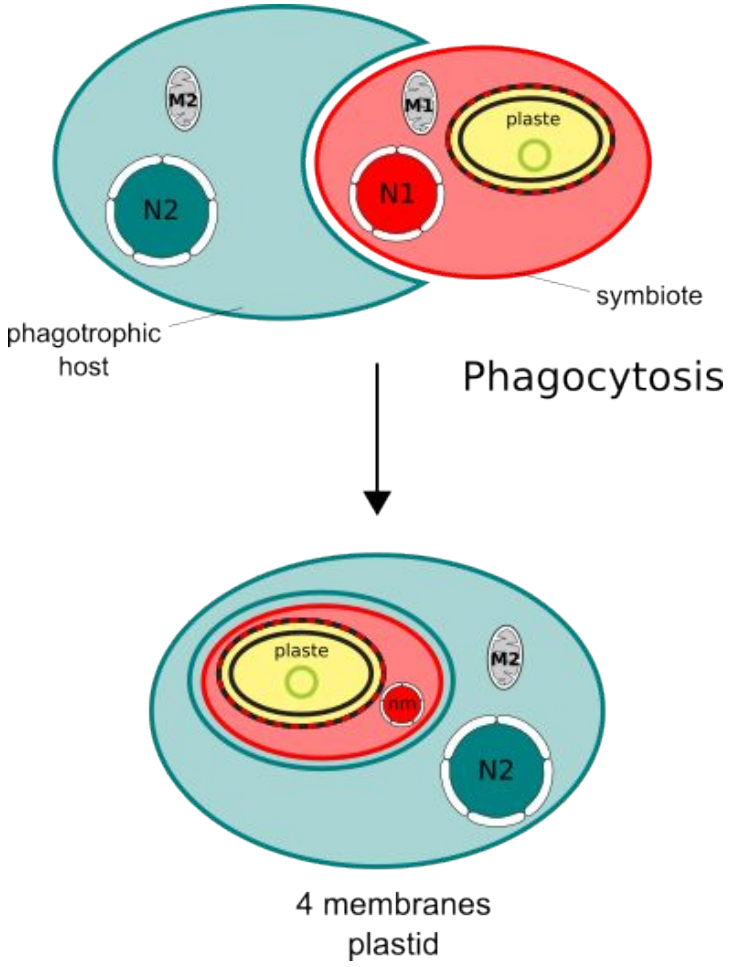


Strong selection pressure !

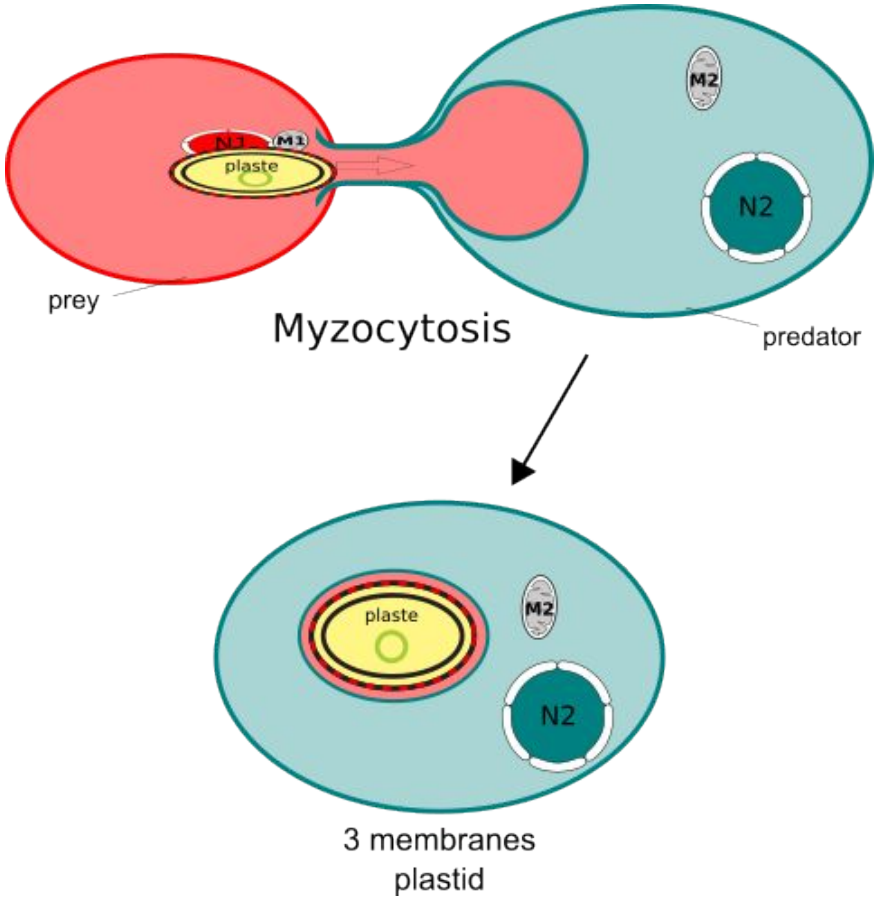
Bodył A. Did some red alga-derived plastids evolve via kleptoplastidy? A hypothesis. Biol Rev. 2018;93:201–22.
Karnkowska A, Yubuki N, Maruyama M, Yamaguchi A, Kashiyama Y, Suzaki T, et al. Proc Natl Acad Sci U S A. 2023;120.

Origin of 3-membrane plastids?

Endosymbiosis (conservative)



Kleptoplasty (non-conservative)



AIM

Use **nuclear-encoded** and **plastid-targeted** gene **diversity** as an **indicator** of **kleptoplasty's** contribution to plastid acquisition among complex algae

Methods

Datasets

Data note | Open access | Published: 17 April 2021

Broadly sampled orthologous groups of eukaryotic proteins for the phylogenetic study of plastid-bearing lineages

Mick Van Vlierberghe, Hervé Philippe & Denis Baurain

BMC Research Notes **14**, Article number: 143 (2021) | Cite this article

- ★ 73 high quality proteomes
- ★ ~ 40 000 photosynthetic clans

Data note | Open access | Published: 09 August 2021

Decontamination, pooling and dereplication of the 678 samples of the Marine Microbial Eukaryote Transcriptome Sequencing Project

Mick Van Vlierberghe, Arnaud Di Franco, Hervé Philippe & Denis Baurain

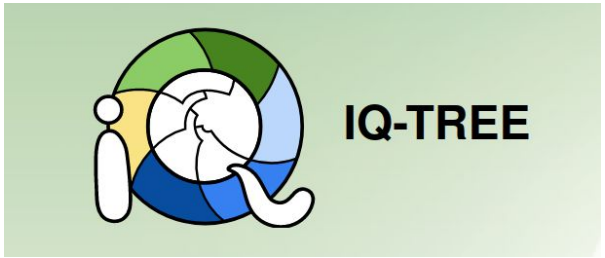
BMC Research Notes **14**, Article number: 306 (2021) | Cite this article

- ★ redundancy [678 -> 260]
- ★ contaminations [260 -> 224]

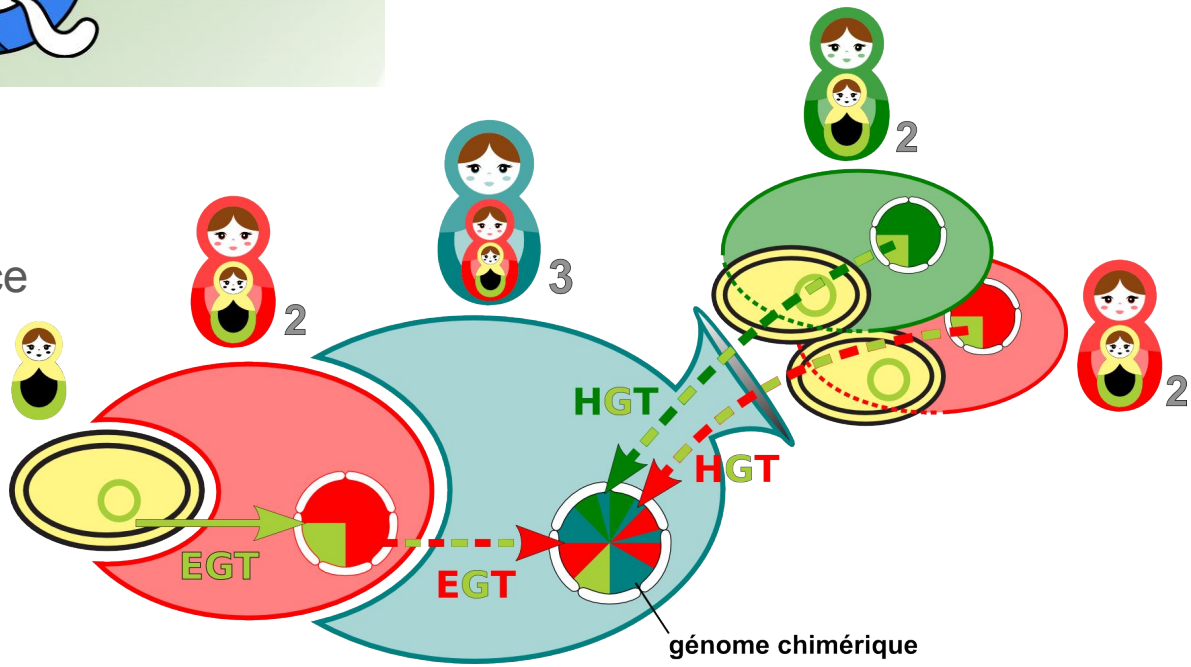
Dataset (1+2)

- ★ Clans `[proteomes]` enrichment `[transcriptomes]`
  - orthology engine
  - https://metacpan.org/pod/Bio::MUST::Apps::FortyTwo

- ★ Tree building

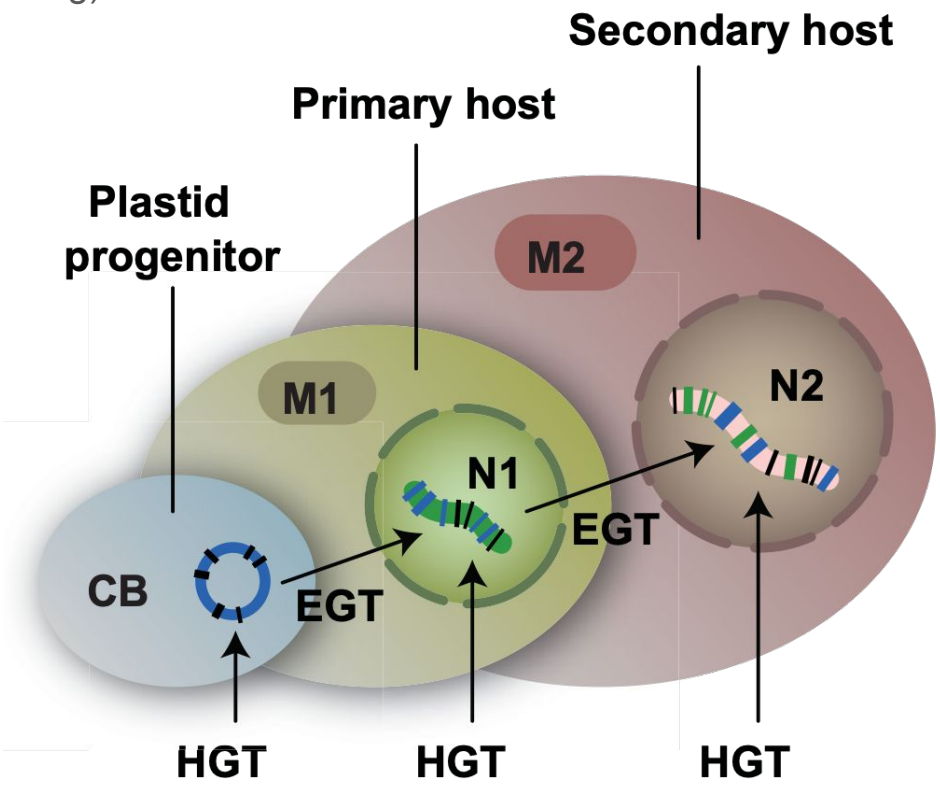


- ★ Automatic tree analysis
  - Gene transfer inference



Automatic tree-parsing and gene transfer inference

- ★ Time constraints
  - primary algae (Archaeplastida)
  - secondary algae (nm-bearing)
  - higher-order algae



Elias M, Archibald JM. BioEssays. 2009;31:1273–9. doi:10.1002/bies.200900117.

Automatic tree-parsing and gene transfer inference

★ Time constraints
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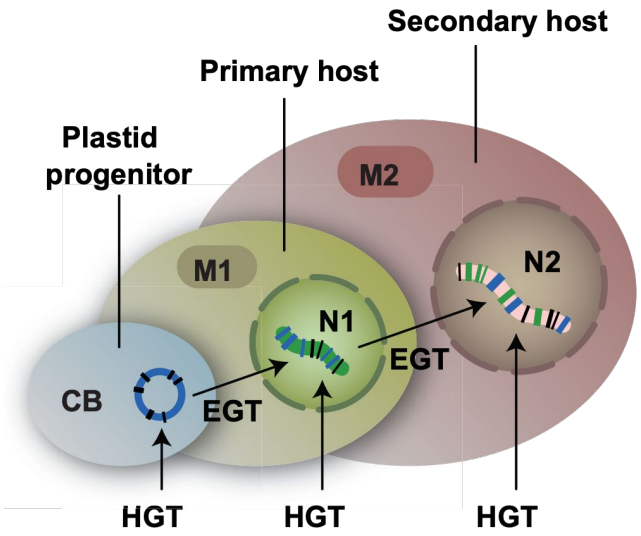
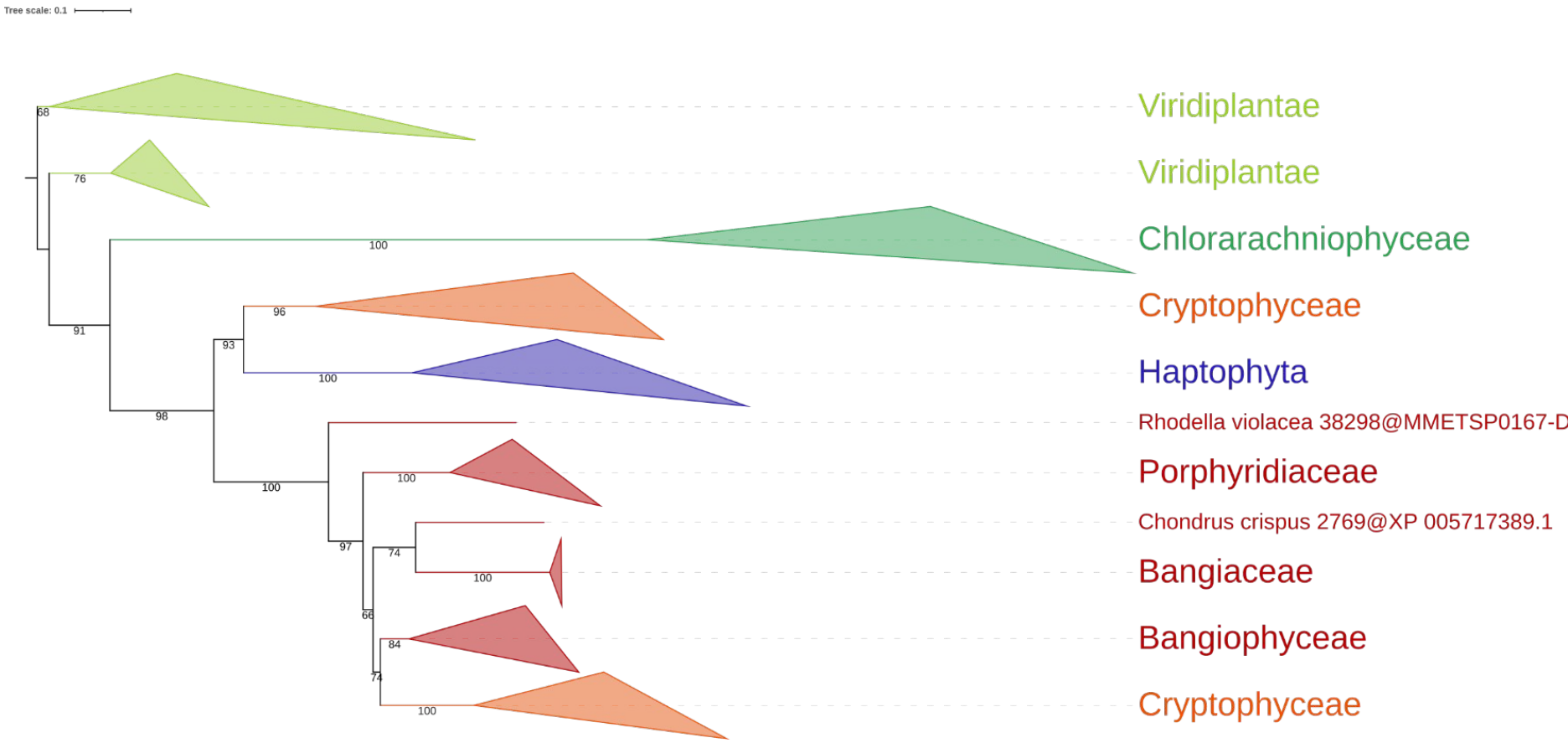
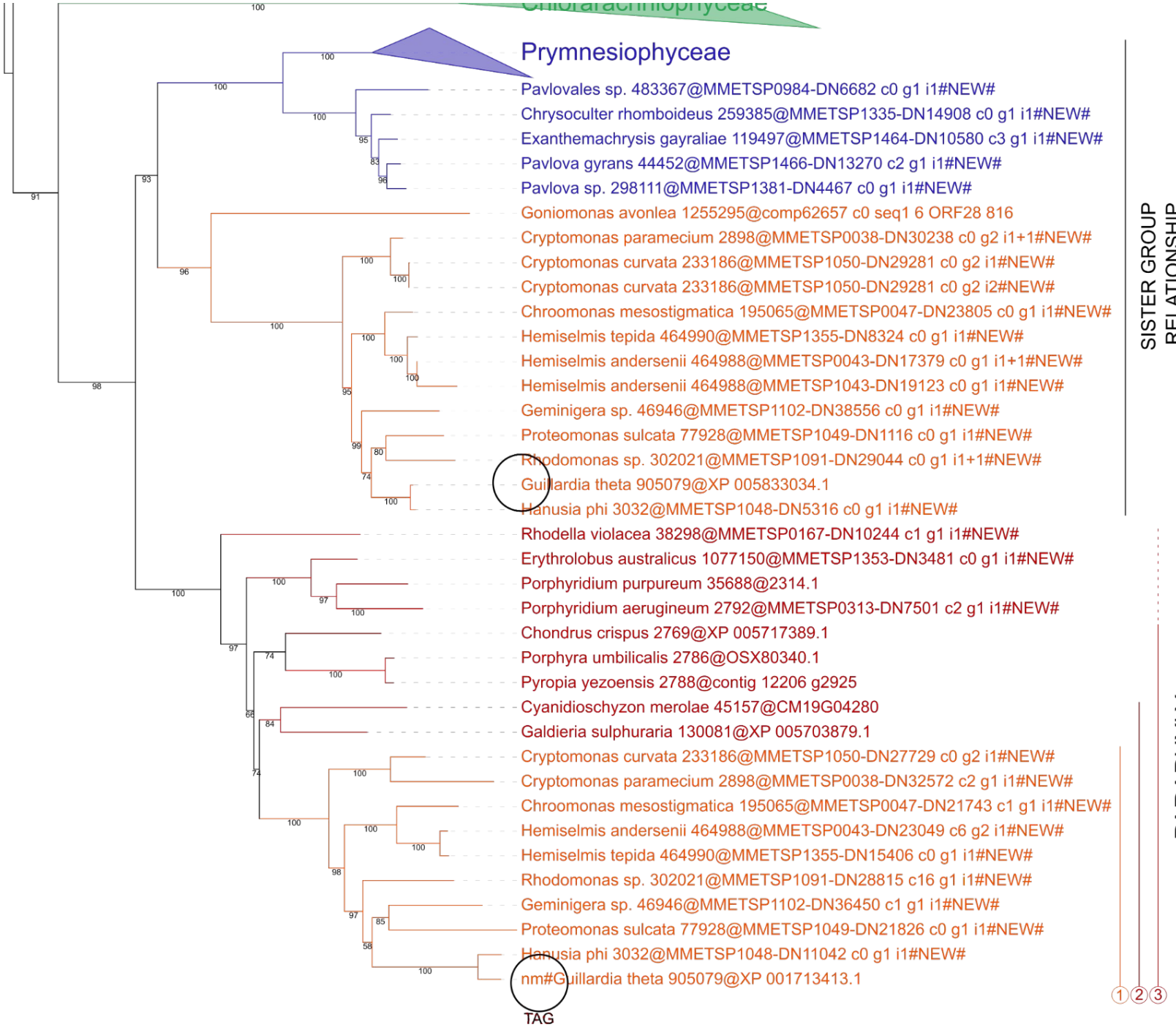


★ Inference by paraphyly detection VS neighbourhood
- exclusive/inclusive

★ Transfer event labelling [receiver tag/donor tag]
- cpcpt#, nm#, nucpt#…

OG0000267-17-IQ-TREE-C20

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Prymnesiophyceae
Pavlovales sp. 483367@MMETSP0984-DN6682 c0 g1 i1#NEW#
Chrysoculter rhomboideus 259385@MMETSP1335-DN14908 c0 g1 i1#NEW#
Exanthemachrysis gayraliae 119497@MMETSP1464-DN10580 c3 g1 i1#NEW#
Pavlova gyrans 44452@MMETSP1466-DN13270 c2 g1 i1#NEW#
Pavlova sp. 298111@MMETSP1381-DN4467 c0 g1 i1#NEW#
Goniomonas avonlea 1255295@comp62657 c0 seq1 6 ORF28 816
Cryptomonas paramecium 2898@MMETSP0038-DN30238 c0 g2 i1+1#NEW#
Cryptomonas curvata 233186@MMETSP1050-DN29281 c0 g2 i1#NEW#
Cryptomonas curvata 233186@MMETSP1050-DN29281 c0 g2 i2#NEW#
Chroomonas mesostigmatica 195065@MMETSP0047-DN23805 c0 g1 i1#NEW#
Hemiselmis tepida 464990@MMETSP1355-DN8324 c0 g1 i1#NEW#
Hemiselmis andersenii 464988@MMETSP0043-DN17379 c0 g1 i1+1#NEW#
Hemiselmis andersenii 464988@MMETSP1043-DN19123 c0 g1 i1#NEW#
Geminigera sp. 46946@MMETSP1102-DN38556 c0 g1 i1#NEW#
Proteomonas sulcata 77928@MMETSP1049-DN1116 c0 g1 i1#NEW#
Rhodomonas sp. 302021@MMETSP1091-DN29044 c0 g1 i1+1#NEW#
Guillardia theta 905079@XP 005833034.1
Hanusia phi 3032@MMETSP1048-DN5316 c0 g1 i1#NEW#
Rhodella violacea 38298@MMETSP0167-DN10244 c1 g1 i1#NEW#
Erythrolobus australicus 1077150@MMETSP1353-DN3481 c0 g1 i1#NEW#
Porphyridium purpureum 35688@2314.1
Porphyridium aerugineum 2792@MMETSP0313-DN7501 c2 g1 i1#NEW#
Chondrus crispus 2769@XP 005717389.1
Porphyra umbilicalis 2786@OSX80340.1
Pyropia yezoensis 2788@contig 12206 g2925
Cyanidioschyzon merolae 45157@CM19G04280
Galdieria sulphuraria 130081@XP 005703879.1
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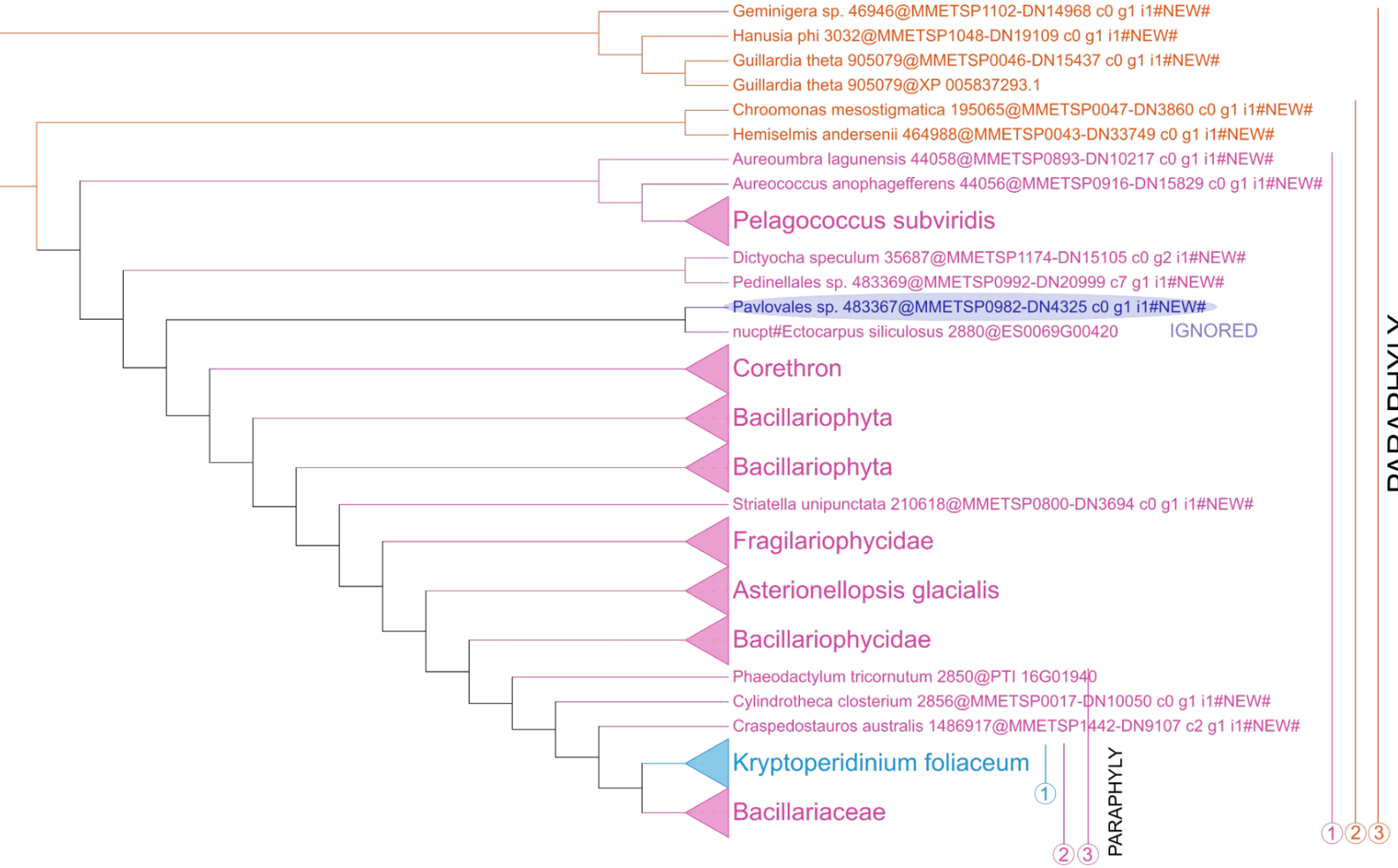
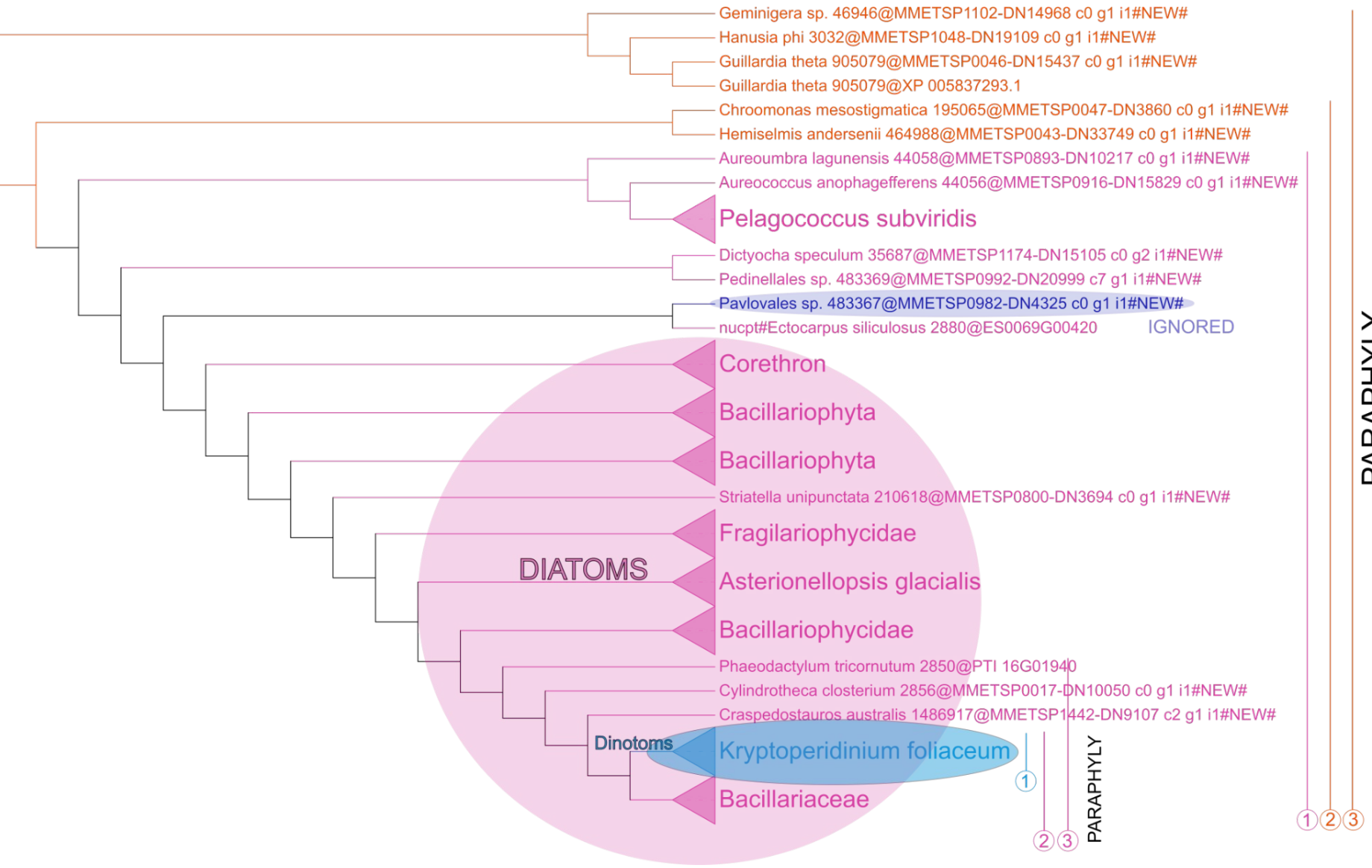
Cryptomonas paramecium 2898@MMETSP0038-DN32572 c2 g1 i1#NEW#
Chroomonas mesostigmatica 195065@MMETSP0047-DN21743 c1 g1 i1#NEW#
Hemiselmis andersenii 464988@MMETSP0043-DN23049 c6 g2 i1#NEW#
Hemiselmis tepida 464990@MMETSP1355-DN15406 c0 g1 i1#NEW#
Rhodomonas sp. 302021@MMETSP1091-DN28815 c16 g1 i1#NEW#
Geminigera sp. 46946@MMETSP1102-DN36450 c1 g1 i1#NEW#
Proteomonas sulcata 77928@MMETSP1049-DN21826 c0 g1 i1#NEW#
Hanusia phi 3032@MMETSP1048-DN11042 c0 g1 i1#NEW#
nm#Guillardia theta 905079@XP 001713413.1
TAG
SISTER GROUP RELATIONSHIP
PARAPHYLY
1
2
3

OG0015365-0-IQ-TREE-C20

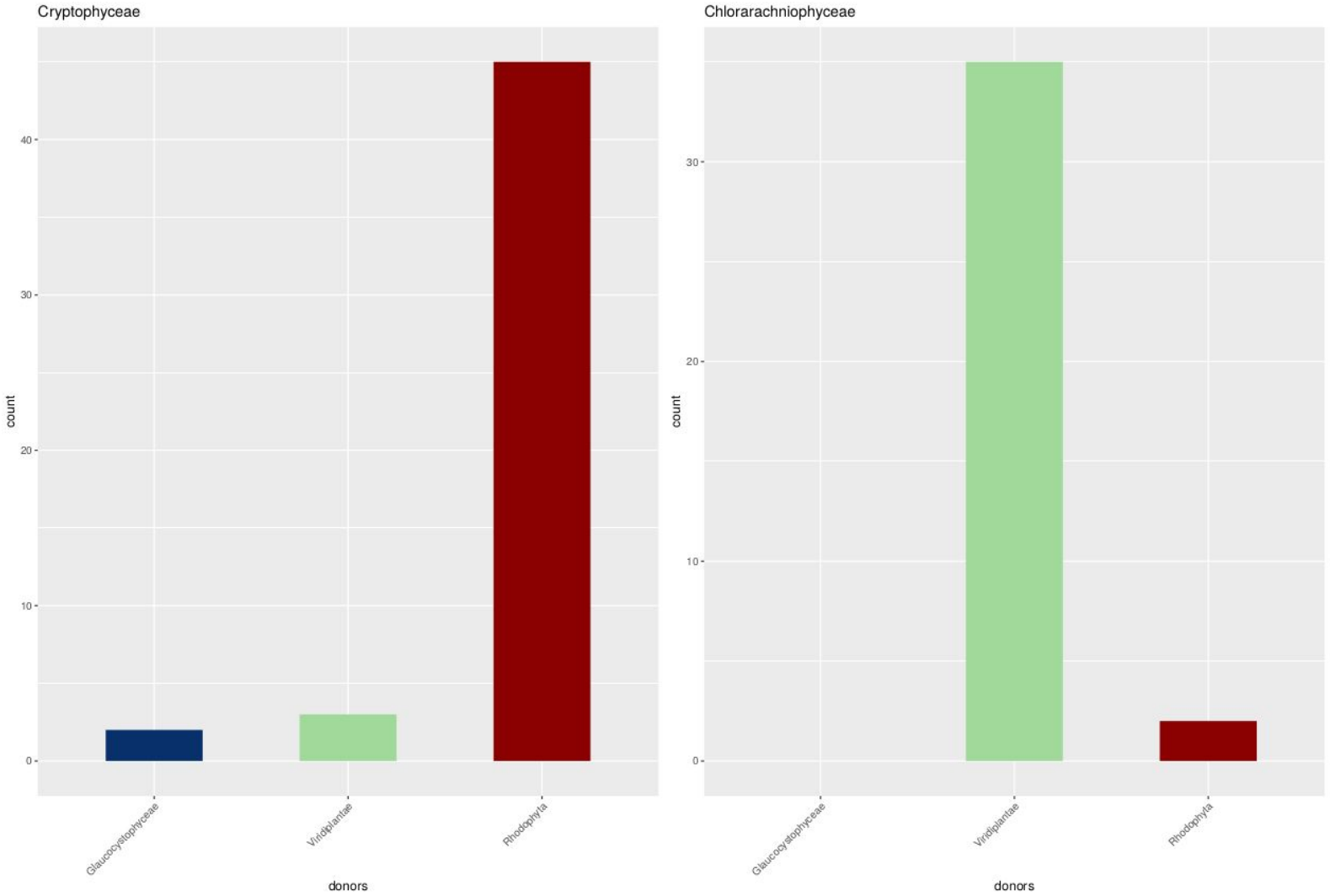


OG0015365-0-IQ-TREE-C20

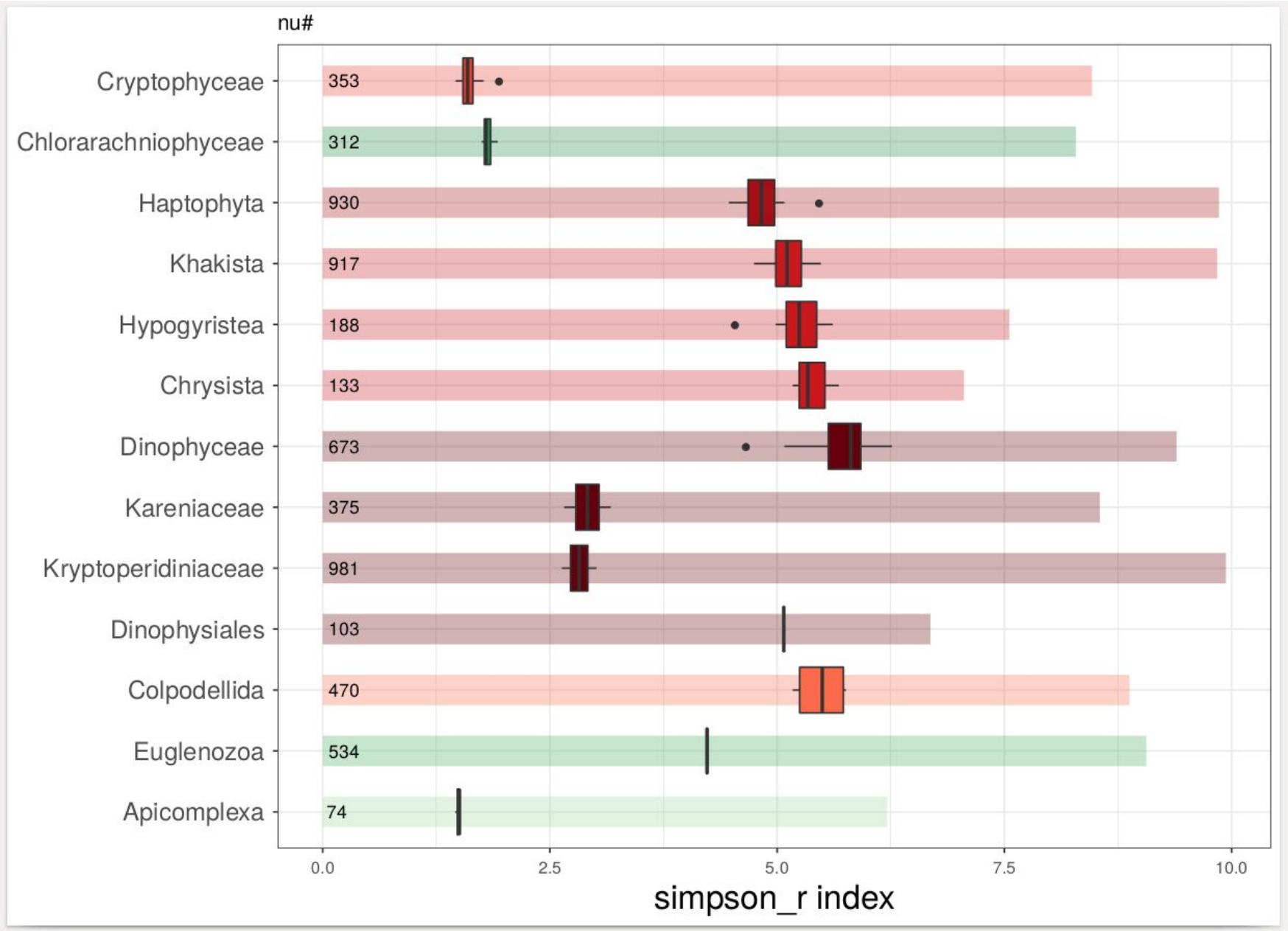



Preliminary results [round 2]

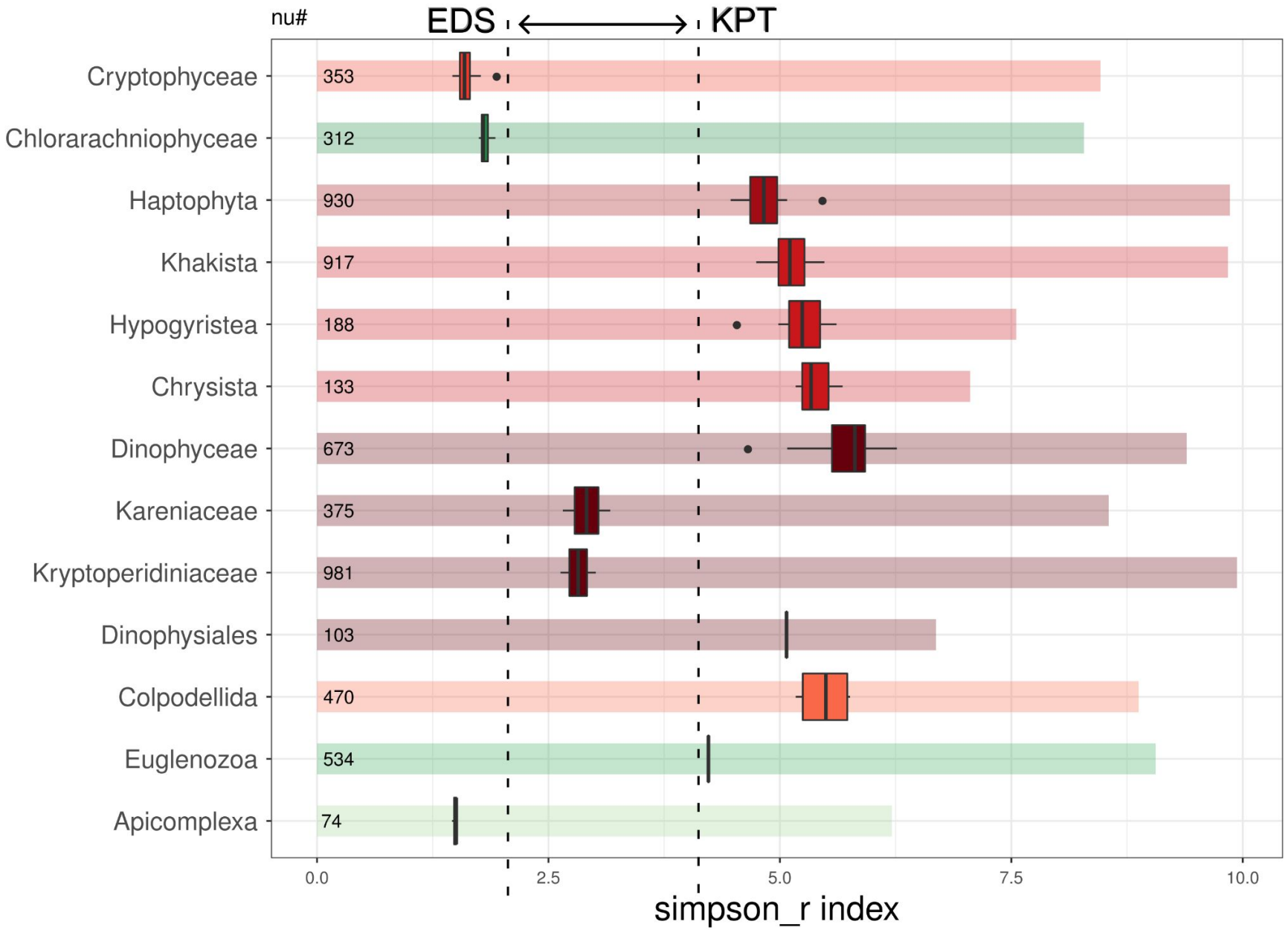
Control set : **cpcpt#**



nucpt# : alpha-diversity



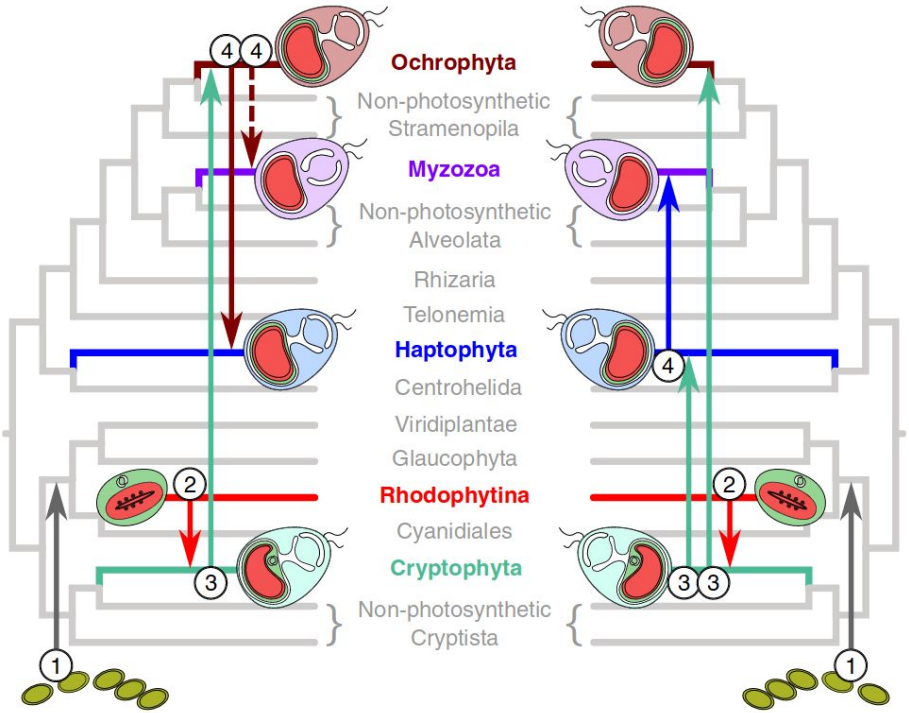
nucpt# : alpha-diversity



Can’t wait for round 3 …

Test robustness

- ★ naive time constraints
- ★ functional annotation
- ★ neighbourhood ?
- ★ sampling bias ?



Strassert JFH, Irisarri I, Williams TA, Burki F. Nat Commun. 2021;12. doi:10.1038/s41467-021-22044-z.

Durandal

Denis Baurain

ULg, B22

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