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The case of horizontal gene transfer from bacteria to the peculiar dinoflagellate plastid genome

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Materials and methods

Collection of sequences and preparation of alignments

To gather all potential homologs to Ycf16 and Ycf24 encoded on the *Ceratium horridum* AF490364 minicircle as well as the sequences of Rpl28, Rpl33, and the potential product of the unannotated open reading frame (FtsY) encoded on the *Pyrocystis lunula* AF490367 minicircle, we carried out comprehensive PSI-BLAST or BLAST searches of non-redundant protein and expressed sequence tag databases in NCBI GenBank (http://blast.ncbi.nlm.nih.gov), Dragonblast (http://dbdata.rutgers.edu/dragon), and the expressed sequence tag database of *Alexandrium tamarense*.[1] The identified sequences were verified by local searches of the Conserved Domain Database[2] for the presence of appropriate domains. Each of the resulting sets of homologs consisted of several thousand sequences. Initial alignments were performed in MAFFT using the slow but accurate algorithm L-INS-i with 1,000 cycles of iterative refinement[3] and edited manually in JalView.[4] Incomplete or fragmentary sequences were excluded from further analyses. Ultimately, more than 100 sequences in each of five protein sets were selected using T-Coffee[5] to remove redundancy from the datasets and to include representatives from various prokaryotic and eukaryotic groups. Final alignments were obtained in T-Coffee using profile information (PSI-Coffee) and combining the output of many alignment methods (M-Coffee).

Phylogenetic analyses

Phylogenetic trees were inferred by six approaches using five programs: PhyloBayes 3.3e (ref. 6), MrBayes 3.2.1 (ref. 7), TreeFinder[8], PhyML-Structure[9], and morePhyML 1.14 (ref. 10) based on PhyML 3.0 (ref. 11). In the PhyloBayes analyses, we applied two substitution models for all alignment sets, LG+Γ(5) and CAT Poisson+Γ(5), with the number of components, weights, and profiles inferred from the data. Two independent Markov chains were run through 100,000 cycles (for the Ycf24 set) or 200,000 cycles (for the other sets) with the former model and through 1,000,000 cycles with the latter model. A posterior consensus was calculated from the last 10,000-500,000 trees from each chain after obtaining convergence and good or acceptable runs. In the MrBayes approach, we assumed the mixed+I+Γ(5) model for all alignment sets to sample appropriate models across the substitution model space in the Bayesian MCMC analysis itself, avoiding the need for a priori model testing. In this analysis, two independent runs starting from random trees were applied, each using eight Markov chains with 40,000,000 generations (for the Rpl28 and Rpl33 sets) or four Markov chains with 20,000,000 generations (for the other sets). Trees were sampled every 100 generations; to calculate a posterior consensus, we selected trees from the last 5,868,000-26,644,000 generations that reached stationary phase and convergence (the standard deviation of split frequencies stabilized and was less than 0.01).

In the TreeFinder approach, we applied appropriate substitution models that were chosen according to the Propose Model module in this program assuming optimized frequencies of amino acids, whereas the models used in (more)PhyML were selected according to ProtTest 3.2 (ref. 12) assuming optimization of models, branches, and topology of the tree (Table 1S). Search depth was set to 2 in TreeFinder, and the best heuristic search algorithms, NNI and SPR, in (more)PhyML were applied. Edge support was assessed by the bootstrap analysis with 1,000 replicates in each of these two programs. Additionally, we applied the Local Rearrangements-Expected Likelihood Weights method in TreeFinder and the approximate likelihood ratio test (aLRT) based on a Shimodaira-Hasegawa-like procedure in morePhyML.[13] In PhyML-Structure, we used the EX_EHO+Γ(5) substitution model for all alignment sets, whereas edge support was calculated by aLRT based on the χ^2 test and a Shimodaira-Hasegawa-like procedure. The minimum of these two aLRT support values is shown at selected nodes in the presented trees (Fig. 1S).

Topology tests with 10,000,000 replicates were performed in Consel v0.20 (ref. 14) to compare trees obtained in PhyloBayes under LG+Γ(5) with alternative topologies that assumed different positions of minicircle *C. horridum* and *P. lunula* sequences (Fig. 1S). Site-wise log-likelihoods for the analyzed trees were calculated in PhyML under the best fitted substitution models found in ProtTest.

Table 1S. Applied substitution models in the analyzed alignment sets.

Alignment set	PhyloBayes	MrBayes	TreeFinder	(more)PhyML	PhyML-Structure
FtsY	LG+Γ(5), CAT Poisson+Γ(5)	mixed+I+Γ(5)	LG+F+I+Γ(5)	LG+Γ(5)	EX_EHO+Γ(5)
Rpl28	LG+Γ(5), CAT Poisson+Γ(5)	mixed+I+Γ(5)	witHIV+I+Γ(5)	LG+F+Γ(5)	EX_EHO+Γ(5)
Rpl33	LG+Γ(5), CAT Poisson+Γ(5)	mixed+I+Γ(5)	MIX+F+Γ(5)	LG+Γ(5)	EX_EHO+Γ(5)
Ycf16	LG+Γ(5), CAT Poisson+Γ(5)	mixed+I+Γ(5)	LG+F+I+Γ(5)	LG+F+Γ(5)	EX_EHO+Γ(5)
Ycf24	LG+Γ(5), CAT Poisson+Γ(5)	mixed+I+Γ(5)	LG+F+Γ(5)	LG+F+Γ(5)	EX_EHO+Γ(5)

References

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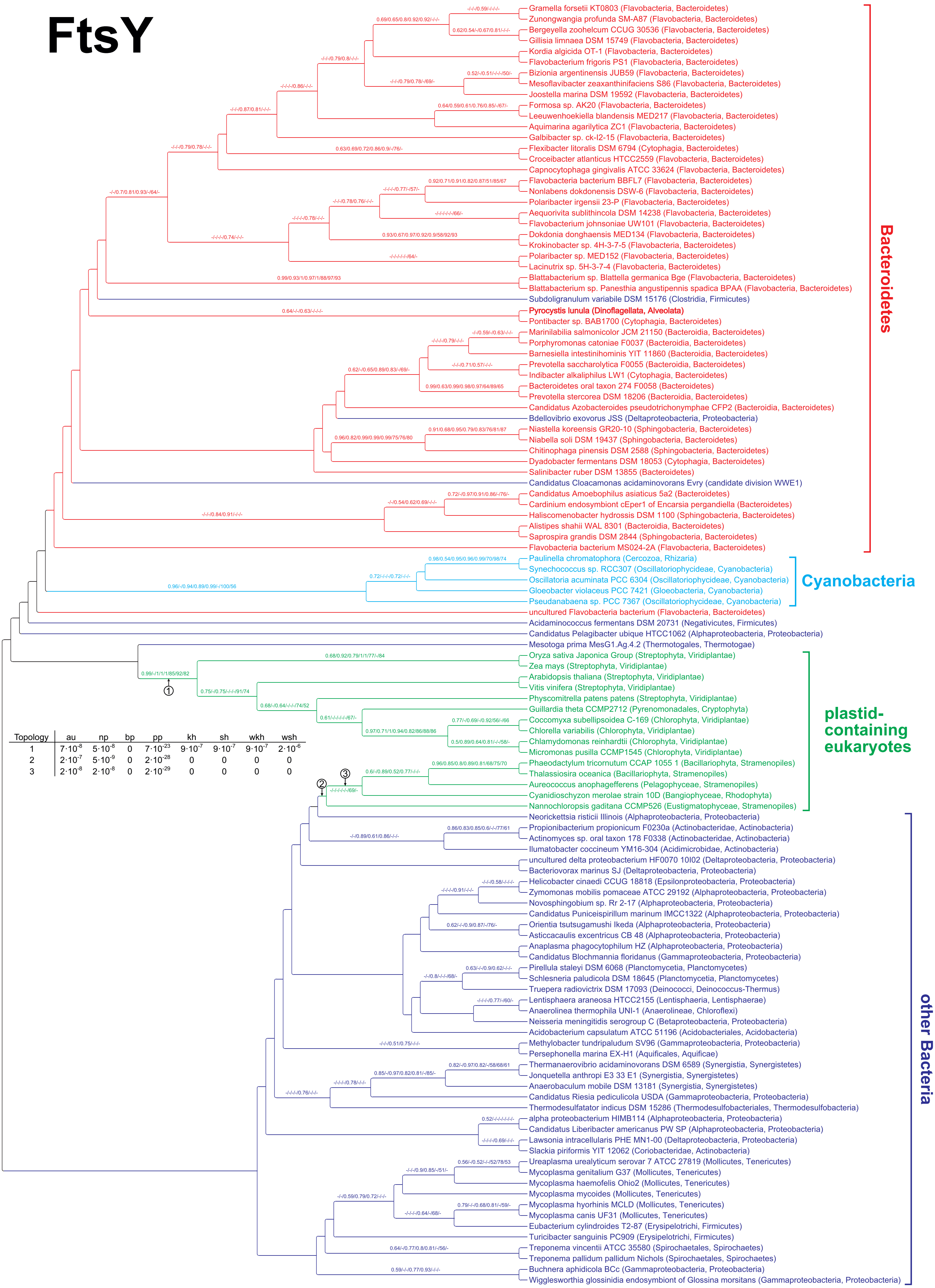
Figure 1S. Phylogenetic trees for FtsY, Rpl28, Rpl33, Ycf16, and Ycf24 sequences inferred in PhyloBayes under the LG+Γ(5) model. Sequences localized to *Pyrocystis lunula* AF490367 and *Ceratium horridum* AF490364 minicircles appear in bold font. Numbers at nodes (in order) correspond to: posterior probabilities estimated in Phylobayes for the LG+Γ(5) and CAT Poisson+Γ(5) models as well as in MrBayes, the minimum of support values calculated by aLRT based on the $\chi 2$ test and a Shimodaira-Hasegawa-like procedure in PhyML-Structure, support values obtained by a Shimodaira-Hasegawa-like procedure in morePhyML, PhyML bootstrap values, Local Rearrangements-Expected Likelihood Weights-support values calculated in TreeFinder, and TreeFinder bootstrap values. Values of the posterior probabilities and bootstrap percentages lower than or equal to 0.50 and 50%, respectively, were omitted or indicated by a dash "-". Tables show the results of topology tests comparing the best topology with alternatives that assume different positions of the minicircle-encoded proteins. Topology test results are: the p-value for the approximately unbiased test (au) calculated from the multiscale bootstrap, the non-parametric bootstrap probability calculated from the multiscale bootstrap (np), the bootstrap probability calculated in the non-multiscale manner (bp), the Bayesian posterior probability calculated by the BIC approximation (pp), and the p-values of the Kishino-Hasegawa test (kh), the Shimodaira-Hasegawa test (sh), the weighted Kishino-Hasegawa test (skh), and the weighted Shimodaira-Hasegawa test (wsh).

FtsY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Zunongwangia profunda SM-A87 (Flavobacteria, Bacteroidetes)
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Bergeyella zoohelcum CCUG 30536 (Flavobacteria, Bacteroidetes)
Gillisia limnaea DSM 15749 (Flavobacteria, Bacteroidetes)
Kordia algicida OT-1 (Flavobacteria, Bacteroidetes)
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Flavobacterium frigoris PS1 (Flavobacteria, Bacteroidetes)
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Bizionia argentinensis JUB59 (Flavobacteria, Bacteroidetes)
-/-/-/0.79/0.78/-/69/-
Mesoflavibacter zeaxanthinifaciens S86 (Flavobacteria, Bacteroidetes)
-/-/-/-/0.86/-/-/-
Joostella marina DSM 19592 (Flavobacteria, Bacteroidetes)
0.64/0.59/0.61/0.76/0.85/-/67/-
Formosa sp. AK20 (Flavobacteria, Bacteroidetes)
-/-/-/0.87/0.81/-/-/-
Leeuwenhoekiella blandensis MED217 (Flavobacteria, Bacteroidetes)
Aquimarina agarilytica ZC1 (Flavobacteria, Bacteroidetes)
Galbibacter sp. ck-I2-15 (Flavobacteria, Bacteroidetes)
-/-/-/0.79/0.78/-/-/-
0.63/0.69/0.72/0.86/0.9/-/76/-
Flexibacter litoralis DSM 6794 (Cytophagia, Bacteroidetes)
Croceibacter atlanticus HTCC2559 (Flavobacteria, Bacteroidetes)
Capnocytophaga gingivalis ATCC 33624 (Flavobacteria, Bacteroidetes)
0.92/0.71/0.91/0.82/0.87/51/85/67
Flavobacteria bacterium BBFL7 (Flavobacteria, Bacteroidetes)
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-/-/-/-/0.77/-/57/-
Nonlabens dokdonensis DSW-6 (Flavobacteria, Bacteroidetes)
-/-/-/0.78/0.76/-/-/-
Polaribacter irgensii 23-P (Flavobacteria, Bacteroidetes)
-/-/-/-/-/-/66/-
Aequorivita sublithincola DSM 14238 (Flavobacteria, Bacteroidetes)
-/-/-/-/0.78/-/-/-
Flavobacterium johnsoniae UW101 (Flavobacteria, Bacteroidetes)
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Krokinobacter sp. 4H-3-7-5 (Flavobacteria, Bacteroidetes)
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Polaribacter sp. MED152 (Flavobacteria, Bacteroidetes)
Lacinutrix sp. 5H-3-7-4 (Flavobacteria, Bacteroidetes)
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Blattabacterium sp. Blattella germanica Bge (Flavobacteria, Bacteroidetes)
Blattabacterium sp. Panesthia angustipennis spadica BPAA (Flavobacteria, Bacteroidetes)
Subdoligranulum variabile DSM 15176 (Clostridia, Firmicutes)
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Pyrocystis lunula (Dinoflagellata, Alveolata)
Pontibacter sp. BAB1700 (Cytophagia, Bacteroidetes)
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Barnesiella intestinihominis YIT 11860 (Bacteroidia, Bacteroidetes)
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Indibacter alkaliphilus LW1 (Cytophagia, Bacteroidetes)
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Prevotella stercorea DSM 18206 (Bacteroidia, Bacteroidetes)
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Bdellovibrio exovorus JSS (Deltaproteobacteria, Proteobacteria)
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Niastella koreensis GR20-10 (Sphingobacteria, Bacteroidetes)
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Niabella soli DSM 19437 (Sphingobacteria, Bacteroidetes)
Chitinophaga pinensis DSM 2588 (Sphingobacteria, Bacteroidetes)
Dyadobacter fermentans DSM 18053 (Cytophagia, Bacteroidetes)
Salinibacter ruber DSM 13855 (Bacteroidetes)
Candidatus Cloacamonas acidaminovorans Evry (candidate division WWE1)
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Candidatus Amoebophilus asiaticus 5a2 (Bacteroidetes)
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Cardinium endosymbiont cEper1 of Encarsia pergandiella (Bacteroidetes)
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Haliscomenobacter hydrossis DSM 1100 (Sphingobacteria, Bacteroidetes)
Alistipes shahii WAL 8301 (Bacteroidia, Bacteroidetes)
Saprospira grandis DSM 2844 (Sphingobacteria, Bacteroidetes)
Flavobacteria bacterium MS024-2A (Flavobacteria, Bacteroidetes)
Bacteroidetes
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Pseudanabaena sp. PCC 7367 (Oscillatoriophycideae, Cyanobacteria)
Cyanobacteria
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Acidaminococcus fermentans DSM 20731 (Negativicutes, Firmicutes)
Candidatus Pelagibacter ubique HTCC1062 (Alphaproteobacteria, Proteobacteria)
Mesotoga prima MesG1.Ag.4.2 (Thermotogales, Thermotogae)
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Zea mays (Streptophyta, Viridiplantae)
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Arabidopsis thaliana (Streptophyta, Viridiplantae)
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Thalassiosira oceanica (Bacillariophyta, Stramenopiles)
2
Aureococcus anophagefferens (Pelagophyceae, Stramenopiles)
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Cyanidioschyzon merolae strain 10D (Bangiophyceae, Rhodophyta)
Nannochloropsis gaditana CCMP526 (Eustigmatophyceae, Stramenopiles)
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uncultured delta proteobacterium HF0070 10I02 (Deltaproteobacteria, Proteobacteria)
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Helicobacter cinaedi CCUG 18818 (Epsilonproteobacteria, Proteobacteria)
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Asticcacaulis excentricus CB 48 (Alphaproteobacteria, Proteobacteria)
Anaplasma phagocytophilum HZ (Alphaproteobacteria, Proteobacteria)
Candidatus Blochmannia floridanus (Gammaproteobacteria, Proteobacteria)
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Schlesneria paludicola DSM 18645 (Planctomycetia, Planctomycetes)
Truepera radiovictrix DSM 17093 (Deinococci, Deinococcus-Thermus)
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Anaerolinea thermophila UNI-1 (Anaerolineae, Chloroflexi)
Neisseria meningitidis serogroup C (Betaproteobacteria, Proteobacteria)
Acidobacterium capsulatum ATCC 51196 (Acidobacteriales, Acidobacteria)
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Persephonella marina EX-H1 (Aquificales, Aquificae)
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Thermanaerovibrio acidaminovorans DSM 6589 (Synergistia, Synergistetes)
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Jonquetella anthropi E3 33 E1 (Synergistia, Synergistetes)
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Anaerobaculum mobile DSM 13181 (Synergistia, Synergistetes)
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Thermodesulfatator indicus DSM 15286 (Thermodesulfobacteriales, Thermodesulfobacteria)
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alpha proteobacterium HIMB114 (Alphaproteobacteria, Proteobacteria)
Candidatus Liberibacter americanus PW SP (Alphaproteobacteria, Proteobacteria)
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Lawsonia intracellularis PHE MN1-00 (Deltaproteobacteria, Proteobacteria)
Slackia piriformis YIT 12062 (Coriobacteridae, Actinobacteria)
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Ureaplasma urealyticum serovar 7 ATCC 27819 (Mollicutes, Tenericutes)
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Mycoplasma genitalium G37 (Mollicutes, Tenericutes)
Mycoplasma haemofelis Ohio2 (Mollicutes, Tenericutes)
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Mycoplasma hyorhinis MCLD (Mollicutes, Tenericutes)
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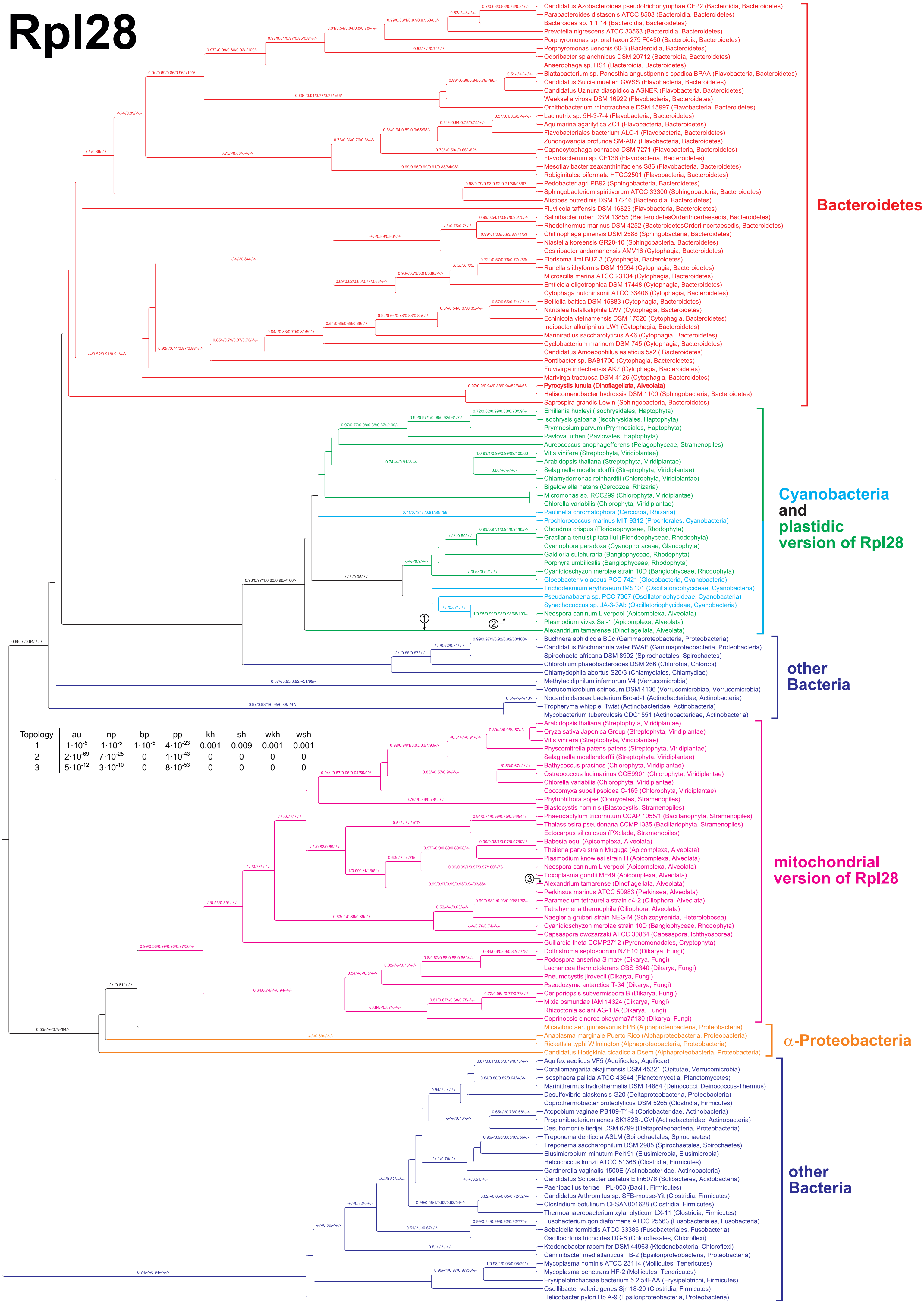
Mycoplasma canis UF31 (Mollicutes, Tenericutes)
Eubacterium cylindroides T2-87 (Erysipelotrichi, Firmicutes)
Turicibacter sanguinis PC909 (Erysipelotrichi, Firmicutes)
0.64/-/-/0.77/0.8/0.81/-/56/-
Treponema vincentii ATCC 35580 (Spirochaetales, Spirochaetes)
Treponema pallidum pallidum Nichols (Spirochaetales, Spirochaetes)
0.59/-/-/0.77/0.93/-/-/-
Buchnera aphidicola BCc (Gammaproteobacteria, Proteobacteria)
Wigglesworthia glossinidia endosymbiont of Glossina morsitans (Gammaproteobacteria, Proteobacteria)
other Bacteria

Topology	au	np	bp	pp	kh	sh	wkh	wsh
1	$7\cdot10^{-8}$	$5\cdot10^{-8}$	0	$7\cdot10^{-23}$	$9\cdot10^{-7}$	$9\cdot10^{-7}$	$9\cdot10^{-7}$	$2\cdot10^{-6}$
2	$2\cdot10^{-7}$	$5\cdot10^{-9}$	0	$2\cdot10^{-28}$	0	0	0	0
3	$2\cdot10^{-8}$	$2\cdot10^{-8}$	0	$2\cdot10^{-29}$	0	0	0	0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Prevotella nigrescens ATCC 33563 (Bacteroidia, Bacteroidetes)
Porphyromonas sp. oral taxon 279 F0450 (Bacteroidia, Bacteroidetes)
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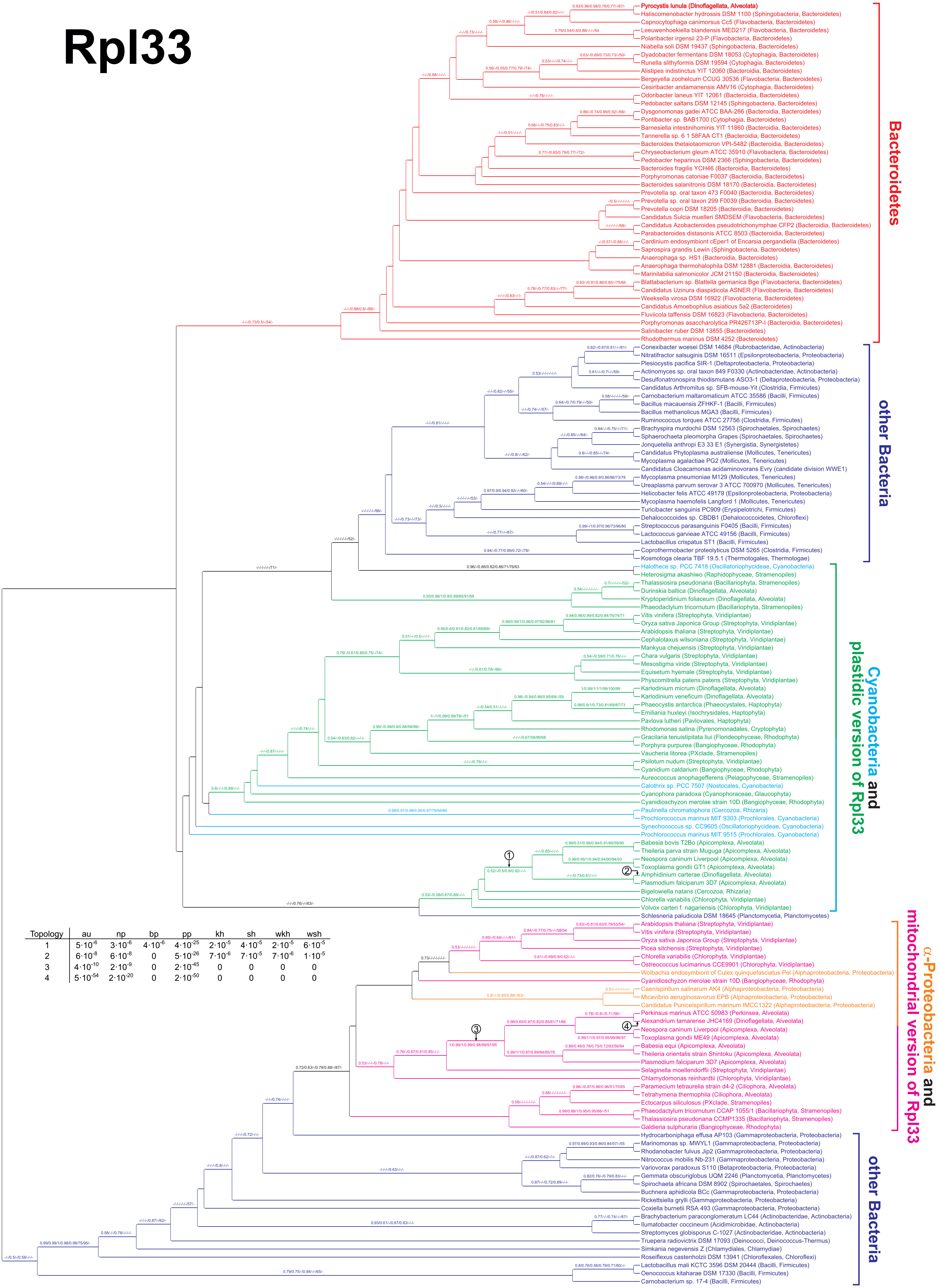
Anaerophaga sp. HS1 (Bacteroidia, Bacteroidetes)
Blattabacterium sp. Panesthia angustipennis spadica BPAA (Flavobacteria, Bacteroidetes)
Candidatus Sulcia muelleri GWSS (Flavobacteria, Bacteroidetes)
Candidatus Uzinura diaspidicola ASNER (Flavobacteria, Bacteroidetes)
Weeksella virosa DSM 16922 (Flavobacteria, Bacteroidetes)
Ornithobacterium rhinotracheale DSM 15997 (Flavobacteria, Bacteroidetes)
Lacinutrix sp. 5H-3-7-4 (Flavobacteria, Bacteroidetes)
Aquimarina agarilytica ZC1 (Flavobacteria, Bacteroidetes)
Flavobacteriales bacterium ALC-1 (Flavobacteria, Bacteroidetes)
Zunongwangia profunda SM-A87 (Flavobacteria, Bacteroidetes)
Capnocytophaga ochracea DSM 7271 (Flavobacteria, Bacteroidetes)
Flavobacterium sp. CF136 (Flavobacteria, Bacteroidetes)
Mesoflavibacter zeaxanthinifaciens S86 (Flavobacteria, Bacteroidetes)
Robiginitalea biformata HTCC2501 (Flavobacteria, Bacteroidetes)
Pedobacter agri PB92 (Sphingobacteria, Bacteroidetes)
Sphingobacterium spiritivorum ATCC 33300 (Sphingobacteria, Bacteroidetes)
Alistipes putredinis DSM 17216 (Bacteroidia, Bacteroidetes)
Fluviicola taffensis DSM 16823 (Flavobacteria, Bacteroidetes)
Salinibacter ruber DSM 13855 (BacteroidetesOrderiIncertaesedis, Bacteroidetes)
Rhodothermus marinus DSM 4252 (BacteroidetesOrderiIncertaesedis, Bacteroidetes)
Chitinophaga pinensis DSM 2588 (Sphingobacteria, Bacteroidetes)
Niastella koreensis GR20-10 (Sphingobacteria, Bacteroidetes)
Cesiribacter andamanensis AMV16 (Cytophagia, Bacteroidetes)
Fibrisoma limi BUZ 3 (Cytophagia, Bacteroidetes)
Runella slithyformis DSM 19594 (Cytophagia, Bacteroidetes)
Microscilla marina ATCC 23134 (Cytophagia, Bacteroidetes)
Emticicia oligotrophica DSM 17448 (Cytophagia, Bacteroidetes)
Cytophaga hutchinsonii ATCC 33406 (Cytophagia, Bacteroidetes)
Belliella baltica DSM 15883 (Cytophagia, Bacteroidetes)
Nitritalea halalkaliphila LW7 (Cytophagia, Bacteroidetes)
Echinicola vietnamensis DSM 17526 (Cytophagia, Bacteroidetes)
Indibacter alkaliphilus LW1 (Cytophagia, Bacteroidetes)
Mariniradius saccharolyticus AK6 (Cytophagia, Bacteroidetes)
Cyclobacterium marinum DSM 745 (Cytophagia, Bacteroidetes)
Candidatus Amoebophilus asiaticus 5a2 (Bacteroidetes)
Pontibacter sp. BAB1700 (Cytophagia, Bacteroidetes)
Fulvivirga imtechensis AK7 (Cytophagia, Bacteroidetes)
Marivirga tractuosa DSM 4126 (Cytophagia, Bacteroidetes)
Pyrocystis lunula (Dinoflagellata, Alveolata)
Haliscomenobacter hydrossis DSM 1100 (Sphingobacteria, Bacteroidetes)
Saprospira grandis Lewin (Sphingobacteria, Bacteroidetes)
Bacteroidetes
Emiliania huxleyi (Isochrysidales, Haptophyta)
Isochrysis galbana (Isochrysidales, Haptophyta)
Prymnesium parvum (Prymnesiales, Haptophyta)
Pavlova lutheri (Pavlovales, Haptophyta)
Aureococcus anophagefferens (Pelagophyceae, Stramenopiles)
Vitis vinifera (Streptophyta, Viridiplantae)
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Selaginella moellendorffii (Streptophyta, Viridiplantae)
Chlamydomonas reinhardtii (Chlorophyta, Viridiplantae)
Bigelowiella natans (Cercozoa, Rhizaria)
Micromonas sp. RCC299 (Chlorophyta, Viridiplantae)
Chlorella variabilis (Chlorophyta, Viridiplantae)
Paulinella chromatophora (Cercozoa, Rhizaria)
Prochlorococcus marinus MIT 9312 (Prochlorales, Cyanobacteria)
Chondrus crispus (Florideophyceae, Rhodophyta)
Gracilaria tenuistipitata liui (Florideophyceae, Rhodophyta)
Cyanophora paradoxa (Cyanophoraceae, Glaucophyta)
Galdieria sulphuraria (Bangiophyceae, Rhodophyta)
Porphyra umbilicalis (Bangiophyceae, Rhodophyta)
Cyanidioschyzon merolae strain 10D (Bangiophyceae, Rhodophyta)
Gloeobacter violaceus PCC 7421 (Gloeobacteria, Cyanobacteria)
Trichodesmium erythraeum IMS101 (Oscillatoriophycideae, Cyanobacteria)
Pseudanabaena sp. PCC 7367 (Oscillatoriophycideae, Cyanobacteria)
Synechococcus sp. JA-3-3Ab (Oscillatoriophycideae, Cyanobacteria)
Neospora caninum Liverpool (Apicomplexa, Alveolata)
Plasmodium vivax Sal-1 (Apicomplexa, Alveolata)
Alexandrium tamarense (Dinoflagellata, Alveolata)
1
2
Cyanobacteria
and
plastidic
version of Rpl28
Buchnera aphidicola BCc (Gammaproteobacteria, Proteobacteria)
Candidatus Blochmannia vafer BVAF (Gammaproteobacteria, Proteobacteria)
Spirochaeta africana DSM 8902 (Spirochaetales, Spirochaetes)
Chlorobium phaeobacteroides DSM 266 (Chlorobia, Chlorobi)
Chlamydophila abortus S26/3 (Chlamydiales, Chlamydiae)
Methylacidiphilum infernorum V4 (Verrucomicrobia)
Verrucomicrobium spinosum DSM 4136 (Verrucomicrobiae, Verrucomicrobia)
Nocardioidaceae bacterium Broad-1 (Actinobacteridae, Actinobacteria)
Tropheryma whipplei Twist (Actinobacteridae, Actinobacteria)
Mycobacterium tuberculosis CDC1551 (Actinobacteridae, Actinobacteria)
other
Bacteria
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Oryza sativa Japonica Group (Streptophyta, Viridiplantae)
Vitis vinifera (Streptophyta, Viridiplantae)
Physcomitrella patens patens (Streptophyta, Viridiplantae)
Selaginella moellendorffii (Streptophyta, Viridiplantae)
Bathycoccus prasinos (Chlorophyta, Viridiplantae)
Ostreococcus lucimarinus CCE9901 (Chlorophyta, Viridiplantae)
Chlorella variabilis (Chlorophyta, Viridiplantae)
Coccomyxa subellipsoidea C-169 (Chlorophyta, Viridiplantae)
Phytophthora sojae (Oomycetes, Stramenopiles)
Blastocystis hominis (Blastocystis, Stramenopiles)
Phaeodactylum tricornutum CCAP 1055/1 (Bacillariophyta, Stramenopiles)
Thalassiosira pseudonana CCMP1335 (Bacillariophyta, Stramenopiles)
Ectocarpus siliculosus (PXclade, Stramenopiles)
Babesia equi (Apicomplexa, Alveolata)
Theileria parva strain Muguga (Apicomplexa, Alveolata)
Plasmodium knowlesi strain H (Apicomplexa, Alveolata)
Neospora caninum Liverpool (Apicomplexa, Alveolata)
Toxoplasma gondii ME49 (Apicomplexa, Alveolata)
3
Alexandrium tamarense (Dinoflagellata, Alveolata)
Perkinsus marinus ATCC 50983 (Perkinsea, Alveolata)
Paramecium tetraurelia strain d4-2 (Ciliophora, Alveolata)
Tetrahymena thermophila (Ciliophora, Alveolata)
Naegleria gruberi strain NEG-M (Schizopyrenida, Heterolobosea)
Cyanidioschyzon merolae strain 10D (Bangiophyceae, Rhodophyta)
Capsaspora owczarzaki ATCC 30864 (Capsaspora, Ichthyosporea)
Guillardia theta CCMP2712 (Pyrenomonadales, Cryptophyta)
Dothistroma septosporum NZE10 (Dikarya, Fungi)
Podospora anserina S mat+ (Dikarya, Fungi)
Lachancea thermotolerans CBS 6340 (Dikarya, Fungi)
Pneumocystis jirovecii (Dikarya, Fungi)
Pseudozyma antarctica T-34 (Dikarya, Fungi)
Ceriporiopsis subvermispora B (Dikarya, Fungi)
Mixia osmundae IAM 14324 (Dikarya, Fungi)
Rhizoctonia solani AG-1 IA (Dikarya, Fungi)
Coprinopsis cinerea okayama7#130 (Dikarya, Fungi)
mitochondrial
version of Rpl28
Micavibrio aeruginosavorus EPB (Alphaproteobacteria, Proteobacteria)
Anaplasma marginale Puerto Rico (Alphaproteobacteria, Proteobacteria)
Rickettsia typhi Wilmington (Alphaproteobacteria, Proteobacteria)
Candidatus Hodgkinia cicadicola Dsem (Alphaproteobacteria, Proteobacteria)
α-Proteobacteria
Aquifex aeolicus VF5 (Aquificales, Aquificae)
Coraliomargarita akajimensis DSM 45221 (Opitutae, Verrucomicrobia)
Isosphaera pallida ATCC 43644 (Planctomycetia, Planctomycetes)
Marinithermus hydrothermalis DSM 14884 (Deinococci, Deinococcus-Thermus)
Desulfovibrio alaskensis G20 (Deltaproteobacteria, Proteobacteria)
Coprothermobacter proteolyticus DSM 5265 (Clostridia, Firmicutes)
Atopobium vaginae PB189-T1-4 (Coriobacteridae, Actinobacteria)
Propionibacterium acnes SK182B-JCVI (Actinobacteridae, Actinobacteria)
Desulfomonile tiedjei DSM 6799 (Deltaproteobacteria, Proteobacteria)
Treponema denticola ASLM (Spirochaetales, Spirochaetes)
Treponema saccharophilum DSM 2985 (Spirochaetales, Spirochaetes)
Elusimicrobium minutum Pei191 (Elusimicrobia, Elusimicrobia)
Helcococcus kunzii ATCC 51366 (Clostridia, Firmicutes)
Gardnerella vaginalis 1500E (Actinobacteridae, Actinobacteria)
Candidatus Solibacter usitatus Ellin6076 (Solibacteres, Acidobacteria)
Paenibacillus terrae HPL-003 (Bacilli, Firmicutes)
Candidatus Arthromitus sp. SFB-mouse-Yit (Clostridia, Firmicutes)
Clostridium botulinum CFSAN001628 (Clostridia, Firmicutes)
Thermoanaerobacterium xylanolyticum LX-11 (Clostridia, Firmicutes)
Fusobacterium gonidiaformans ATCC 25563 (Fusobacteriales, Fusobacteria)
Sebaldella termitidis ATCC 33386 (Fusobacteriales, Fusobacteria)
Oscillochloris trichoides DG-6 (Chloroflexales, Chloroflexi)
Ktedonobacter racemifer DSM 44963 (Ktedonobacteria, Chloroflexi)
Caminibacter mediatlanticus TB-2 (Epsilonproteobacteria, Proteobacteria)
Mycoplasma hominis ATCC 23114 (Mollicutes, Tenericutes)
Mycoplasma penetrans HF-2 (Mollicutes, Tenericutes)
Erysipelotrichaceae bacterium 5 2 54FAA (Erysipelotrichi, Firmicutes)
Oscillibacter valericigenes Sjm18-20 (Clostridia, Firmicutes)
Helicobacter pylori Hp A-9 (Epsilonproteobacteria, Proteobacteria)
other
Bacteria

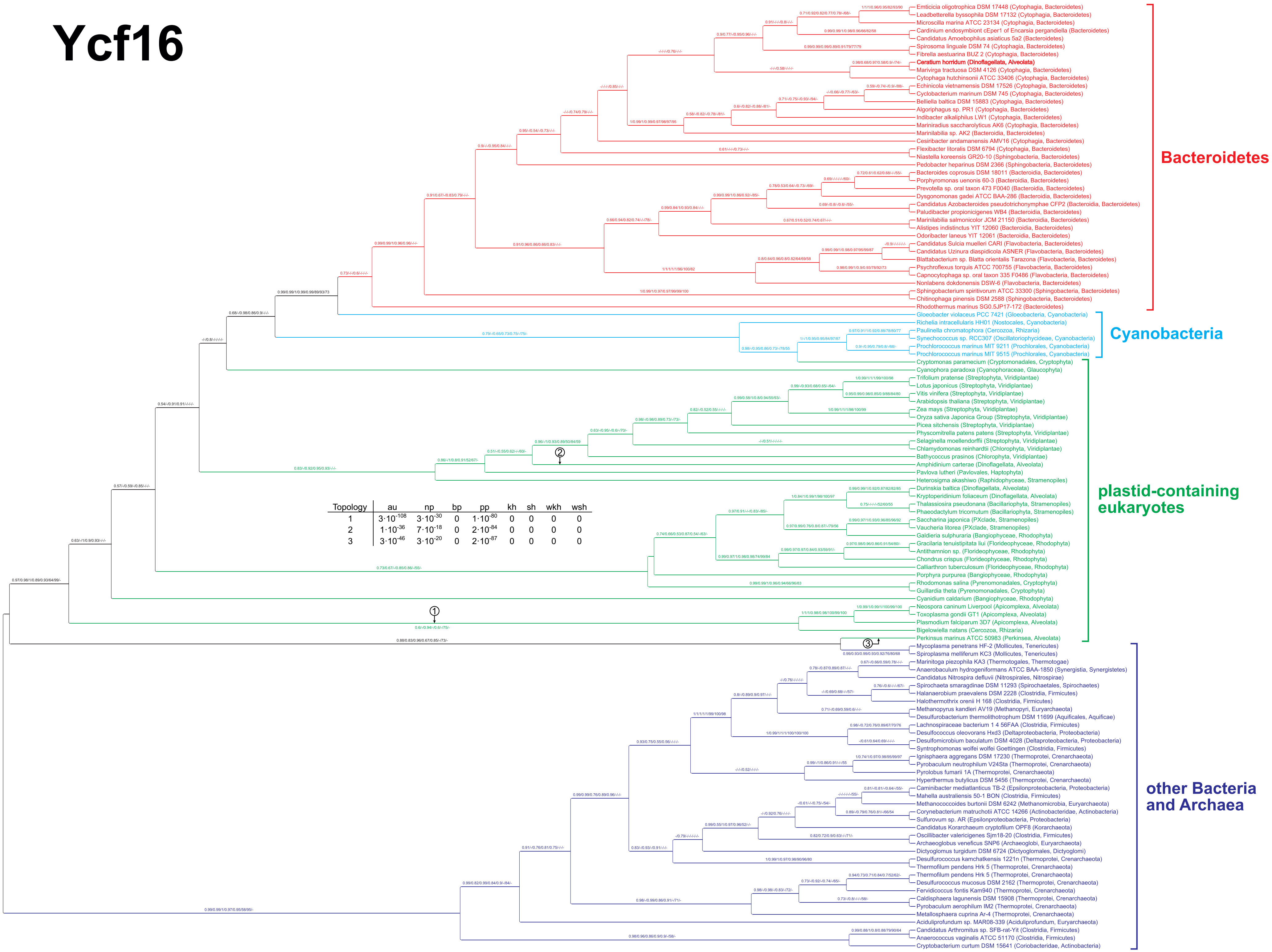
Topology	au	np	bp	pp	kh	sh	wkh	wsh
1	$1\cdot10^{-5}$	$1\cdot10^{-5}$	$1\cdot10^{-5}$	$4\cdot10^{-23}$	0.001	0.009	0.001	0.001
2	$2\cdot10^{-69}$	$7\cdot10^{-25}$	0	$1\cdot10^{-43}$	0	0	0	0
3	$5\cdot10^{-12}$	$3\cdot10^{-10}$	0	$8\cdot10^{-53}$	0	0	0	0

Rpl33


Pyrocystis lunula (Dinoflagellata, Alveolata)
Haliscomenobacter hydrossis DSM 1100 (Sphingobacteria, Bacteroidetes)
Capnocytophaga canimorsus Cc5 (Flavobacteria, Bacteroidetes)
Leeuwenhoekiella blandensis MED217 (Flavobacteria, Bacteroidetes)
Polaribacter irgensii 23-P (Flavobacteria, Bacteroidetes)
Niabella soli DSM 19437 (Sphingobacteria, Bacteroidetes)
Dyadobacter fermentans DSM 18053 (Cytophagia, Bacteroidetes)
Runella slithyformis DSM 19594 (Cytophagia, Bacteroidetes)
Alistipes indistinctus YIT 12060 (Bacteroidia, Bacteroidetes)
Bergeyella zoohelcum CCUG 30536 (Flavobacteria, Bacteroidetes)
Cesiribacter andamanensis AMV16 (Cytophagia, Bacteroidetes)
Odoribacter laneus YIT 12061 (Bacteroidia, Bacteroidetes)
Pedobacter saltans DSM 12145 (Sphingobacteria, Bacteroidetes)
Dysgonomonas gadei ATCC BAA-286 (Bacteroidia, Bacteroidetes)
Pontibacter sp. BAB1700 (Cytophagia, Bacteroidetes)
Barnesiella intestinihominis YIT 11860 (Bacteroidia, Bacteroidetes)
Tannerella sp. 6 1 58FAA CT1 (Bacteroidia, Bacteroidetes)
Bacteroides thetaiotaomicron VPI-5482 (Bacteroidia, Bacteroidetes)
Chryseobacterium gleum ATCC 35910 (Flavobacteria, Bacteroidetes)
Pedobacter heparinus DSM 2366 (Sphingobacteria, Bacteroidetes)
Bacteroides fragilis YCH46 (Bacteroidia, Bacteroidetes)
Porphyromonas catoniae F0037 (Bacteroidia, Bacteroidetes)
Bacteroides salanitronis DSM 18170 (Bacteroidia, Bacteroidetes)
Prevotella sp. oral taxon 473 F0040 (Bacteroidia, Bacteroidetes)
Prevotella sp. oral taxon 299 F0039 (Bacteroidia, Bacteroidetes)
Prevotella copri DSM 18205 (Bacteroidia, Bacteroidetes)
Candidatus Sulcia muelleri SMDSEM (Flavobacteria, Bacteroidetes)
Candidatus Azobacteroides pseudotrichonymphae CFP2 (Bacteroidia, Bacteroidetes)
Parabacteroides distasonis ATCC 8503 (Bacteroidia, Bacteroidetes)
Cardinium endosymbiont cEper1 of Encarsia pergandiella (Bacteroidetes)
Saprospira grandis Lewin (Sphingobacteria, Bacteroidetes)
Anaerophaga sp. HS1 (Bacteroidia, Bacteroidetes)
Anaerophaga thermohalophila DSM 12881 (Bacteroidia, Bacteroidetes)
Marinilabilia salmonicolor JCM 21150 (Bacteroidia, Bacteroidetes)
Blattabacterium sp. Blattella germanica Bge (Flavobacteria, Bacteroidetes)
Candidatus Uzinura diaspidicola ASNER (Flavobacteria, Bacteroidetes)
Weeksella virosa DSM 16922 (Flavobacteria, Bacteroidetes)
Candidatus Amoebophilus asiaticus 5a2 (Bacteroidetes)
Fluviicola taffensis DSM 16823 (Flavobacteria, Bacteroidetes)
Porphyromonas asaccharolytica PR426713P-I (Bacteroidia, Bacteroidetes)
Salinibacter ruber DSM 13855 (Bacteroidetes)
Rhodothermus marinus DSM 4252 (Bacteroidetes)
Bacteroidetes
Conexibacter woesei DSM 14684 (Rubrobacteridae, Actinobacteria)
Nitratifractor salsuginis DSM 16511 (Epsilonproteobacteria, Proteobacteria)
Plesiocystis pacifica SIR-1 (Deltaproteobacteria, Proteobacteria)
Actinomyces sp. oral taxon 849 F0330 (Actinobacteridae, Actinobacteria)
Desulfonatronospira thiodismutans ASO3-1 (Deltaproteobacteria, Proteobacteria)
Candidatus Arthromitus sp. SFB-mouse-Yit (Clostridia, Firmicutes)
Carnobacterium maltaromaticum ATCC 35586 (Bacilli, Firmicutes)
Bacillus macauensis ZFHKF-1 (Bacilli, Firmicutes)
Bacillus methanolicus MGA3 (Bacilli, Firmicutes)
Ruminococcus torques ATCC 27756 (Clostridia, Firmicutes)
Brachyspira murdochii DSM 12563 (Spirochaetales, Spirochaetes)
Sphaerochaeta pleomorpha Grapes (Spirochaetales, Spirochaetes)
Jonquetella anthropi E3 33 E1 (Synergistia, Synergistetes)
Candidatus Phytoplasma australiense (Mollicutes, Tenericutes)
Mycoplasma agalactiae PG2 (Mollicutes, Tenericutes)
Candidatus Cloacamonas acidaminovorans Evry (candidate division WWE1)
Mycoplasma pneumoniae M129 (Mollicutes, Tenericutes)
Ureaplasma parvum serovar 3 ATCC 700970 (Mollicutes, Tenericutes)
Helicobacter felis ATCC 49179 (Epsilonproteobacteria, Proteobacteria)
Mycoplasma haemofelis Langford 1 (Mollicutes, Tenericutes)
Turicibacter sanguinis PC909 (Erysipelotrichi, Firmicutes)
Dehalococcoides sp. CBDB1 (Dehalococcoidetes, Chloroflexi)
Streptococcus parasanguinis F0405 (Bacilli, Firmicutes)
Lactococcus garvieae ATCC 49156 (Bacilli, Firmicutes)
Lactobacillus crispatus ST1 (Bacilli, Firmicutes)
Coprothermobacter proteolyticus DSM 5265 (Clostridia, Firmicutes)
Kosmotoga olearia TBF 19.5.1 (Thermotogales, Thermotogae)
other Bacteria
Halothece sp. PCC 7418 (Oscillatoriophycideae, Cyanobacteria)
Heterosigma akashiwo (Raphidophyceae, Stramenopiles)
Thalassiosira pseudonana (Bacillariophyta, Stramenopiles)
Durinskia baltica (Dinoflagellata, Alveolata)
Kryptoperidinium foliaceum (Dinoflagellata, Alveolata)
Phaeodactylum tricornutum (Bacillariophyta, Stramenopiles)
Vitis vinifera (Streptophyta, Viridiplantae)
Oryza sativa Japonica Group (Streptophyta, Viridiplantae)
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Cephalotaxus wilsoniana (Streptophyta, Viridiplantae)
Mankyua chejuensis (Streptophyta, Viridiplantae)
Chara vulgaris (Streptophyta, Viridiplantae)
Mesostigma viride (Streptophyta, Viridiplantae)
Equisetum hyemale (Streptophyta, Viridiplantae)
Physcomitrella patens patens (Streptophyta, Viridiplantae)
Karlodinium micrum (Dinoflagellata, Alveolata)
Karlodinium veneficum (Dinoflagellata, Alveolata)
Phaeocystis antarctica (Phaeocystales, Haptophyta)
Emiliania huxleyi (Isochrysidales, Haptophyta)
Pavlova lutheri (Pavlovales, Haptophyta)
Rhodomonas salina (Pyrenomonadales, Cryptophyta)
Gracilaria tenuistipitata liui (Florideophyceae, Rhodophyta)
Porphyra purpurea (Bangiophyceae, Rhodophyta)
Vaucheria litorea (PXclade, Stramenopiles)
Psilotum nudum (Streptophyta, Viridiplantae)
Cyanidium caldarium (Bangiophyceae, Rhodophyta)
Aureococcus anophagefferens (Pelagophyceae, Stramenopiles)
Calothrix sp. PCC 7507 (Nostocales, Cyanobacteria)
Cyanophora paradoxa (Cyanophoraceae, Glaucophyta)
Cyanidioschyzon merolae strain 10D (Bangiophyceae, Rhodophyta)
Paulinella chromatophora (Cercozoa, Rhizaria)
Prochlorococcus marinus MIT 9303 (Prochlorales, Cyanobacteria)
Synechococcus sp. CC9605 (Oscillatoriophycideae, Cyanobacteria)
Prochlorococcus marinus MIT 9515 (Prochlorales, Cyanobacteria)
Babesia bovis T2Bo (Apicomplexa, Alveolata)
Theileria parva strain Muguga (Apicomplexa, Alveolata)
Neospora caninum Liverpool (Apicomplexa, Alveolata)
Toxoplasma gondii GT1 (Apicomplexa, Alveolata)
Amphidinium carterae (Dinoflagellata, Alveolata)
Plasmodium falciparum 3D7 (Apicomplexa, Alveolata)
Bigelowiella natans (Cercozoa, Rhizaria)
Chlorella variabilis (Chlorophyta, Viridiplantae)
Volvox carteri f. nagariensis (Chlorophyta, Viridiplantae)
Schlesneria paludicola DSM 18645 (Planctomycetia, Planctomycetes)
1
2
Cyanobacteria and plastidic version of Rpl33
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Vitis vinifera (Streptophyta, Viridiplantae)
Oryza sativa Japonica Group (Streptophyta, Viridiplantae)
Picea sitchensis (Streptophyta, Viridiplantae)
Chlorella variabilis (Chlorophyta, Viridiplantae)
Ostreococcus lucimarinus CCE9901 (Chlorophyta, Viridiplantae)
Wolbachia endosymbiont of Culex quinquefasciatus Pel (Alphaproteobacteria, Proteobacteria)
Cyanidioschyzon merolae strain 10D (Bangiophyceae, Rhodophyta)
Caenispirillum salinarum AK4 (Alphaproteobacteria, Proteobacteria)
Micavibrio aeruginosavorus EPB (Alphaproteobacteria, Proteobacteria)
Candidatus Puniceispirillum marinum IMCC1322 (Alphaproteobacteria, Proteobacteria)
Perkinsus marinus ATCC 50983 (Perkinsea, Alveolata)
Alexandrium tamarense JHC4169 (Dinoflagellata, Alveolata)
Neospora caninum Liverpool (Apicomplexa, Alveolata)
Toxoplasma gondii ME49 (Apicomplexa, Alveolata)
Babesia equi (Apicomplexa, Alveolata)
Theileria orientalis strain Shintoku (Apicomplexa, Alveolata)
Plasmodium falciparum 3D7 (Apicomplexa, Alveolata)
Selaginella moellendorffii (Streptophyta, Viridiplantae)
Chlamydomonas reinhardtii (Chlorophyta, Viridiplantae)
Paramecium tetraurelia strain d4-2 (Ciliophora, Alveolata)
Tetrahymena thermophila (Ciliophora, Alveolata)
Ectocarpus siliculosus (PXclade, Stramenopiles)
Phaeodactylum tricornutum CCAP 1055/1 (Bacillariophyta, Stramenopiles)
Thalassiosira pseudonana CCMP1335 (Bacillariophyta, Stramenopiles)
Galdieria sulphuraria (Bangiophyceae, Rhodophyta)
3
4
α-Proteobacteria and mitochondrial version of Rpl33
Hydrocarboniphaga effusa AP103 (Gammaproteobacteria, Proteobacteria)
Marinomonas sp. MWYL1 (Gammaproteobacteria, Proteobacteria)
Rhodanobacter fulvus Jip2 (Gammaproteobacteria, Proteobacteria)
Nitrococcus mobilis Nb-231 (Gammaproteobacteria, Proteobacteria)
Variovorax paradoxus S110 (Betaproteobacteria, Proteobacteria)
Gemmata obscuriglobus UQM 2246 (Planctomycetia, Planctomycetes)
Spirochaeta africana DSM 8902 (Spirochaetales, Spirochaetes)
Buchnera aphidicola BCc (Gammaproteobacteria, Proteobacteria)
Rickettsiella grylli (Gammaproteobacteria, Proteobacteria)
Coxiella burnetii RSA 493 (Gammaproteobacteria, Proteobacteria)
Brachybacterium paraconglomeratum LC44 (Actinobacteridae, Actinobacteria)
Ilumatobacter coccineum (Acidimicrobidae, Actinobacteria)
Streptomyces globisporus C-1027 (Actinobacteridae, Actinobacteria)
Truepera radiovictrix DSM 17093 (Deinococci, Deinococcus-Thermus)
Simkania negevensis Z (Chlamydiales, Chlamydiae)
Roseiflexus castenholzii DSM 13941 (Chloroflexales, Chloroflexi)
Lactobacillus mali KCTC 3596 DSM 20444 (Bacilli, Firmicutes)
Oenococcus kitaharae DSM 17330 (Bacilli, Firmicutes)
Carnobacterium sp. 17-4 (Bacilli, Firmicutes)
other Bacteria

Topology	au	np	bp	pp	kh	sh	wkh	wsh
1	$5\cdot10^{-6}$	$3\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-25}$	$2\cdot10^{-5}$	$4\cdot10^{-5}$	$2\cdot10^{-5}$	$6\cdot10^{-5}$
2	$6\cdot10^{-8}$	$6\cdot10^{-8}$	0	$5\cdot10^{-26}$	$7\cdot10^{-6}$	$7\cdot10^{-5}$	$7\cdot10^{-6}$	$1\cdot10^{-5}$
3	$4\cdot10^{-10}$	$2\cdot10^{-9}$	0	$2\cdot10^{-45}$	0	0	0	0
4	$5\cdot10^{-54}$	$2\cdot10^{-20}$	0	$2\cdot10^{-50}$	0	0	0	0

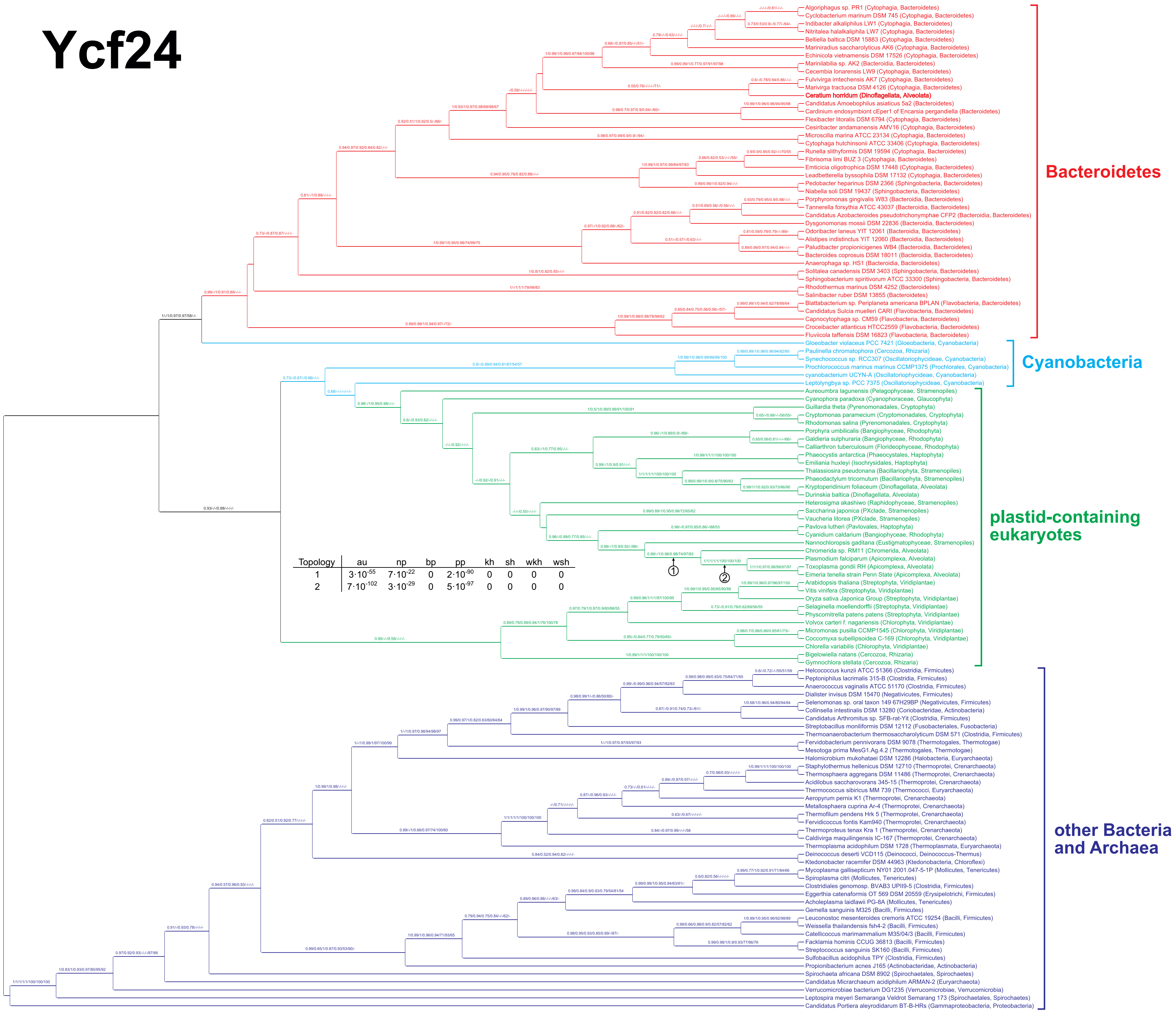
Ycf16



Emticicia oligotrophica DSM 17448 (Cytophagia, Bacteroidetes)
Leadbetterella byssophila DSM 17132 (Cytophagia, Bacteroidetes)
Microscilla marina ATCC 23134 (Cytophagia, Bacteroidetes)
Cardinium endosymbiont cEper1 of Encarsia pergandiella (Bacteroidetes)
Candidatus Amoebophilus asiaticus 5a2 (Bacteroidetes)
Spirosoma linguale DSM 74 (Cytophagia, Bacteroidetes)
Fibrella aestuarina BUZ 2 (Cytophagia, Bacteroidetes)
Ceratium horridum (Dinoflagellata, Alveolata)
Marivirga tractuosa DSM 4126 (Cytophagia, Bacteroidetes)
Cytophaga hutchinsonii ATCC 33406 (Cytophagia, Bacteroidetes)
Echinicola vietnamensis DSM 17526 (Cytophagia, Bacteroidetes)
Cyclobacterium marinum DSM 745 (Cytophagia, Bacteroidetes)
Belliella baltica DSM 15883 (Cytophagia, Bacteroidetes)
Algoriphagus sp. PR1 (Cytophagia, Bacteroidetes)
Indibacter alkaliphilus LW1 (Cytophagia, Bacteroidetes)
Mariniradius saccharolyticus AK6 (Cytophagia, Bacteroidetes)
Marinilabilia sp. AK2 (Bacteroidia, Bacteroidetes)
Cesiribacter andamanensis AMV16 (Cytophagia, Bacteroidetes)
Flexibacter litoralis DSM 6794 (Cytophagia, Bacteroidetes)
Niastella koreensis GR20-10 (Sphingobacteria, Bacteroidetes)
Pedobacter heparinus DSM 2366 (Sphingobacteria, Bacteroidetes)
Bacteroides coprosuis DSM 18011 (Bacteroidia, Bacteroidetes)
Porphyromonas uenonis 60-3 (Bacteroidia, Bacteroidetes)
Prevotella sp. oral taxon 473 F0040 (Bacteroidia, Bacteroidetes)
Dysgonomonas gadei ATCC BAA-286 (Bacteroidia, Bacteroidetes)
Candidatus Azobacteroides pseudotrichonymphae CFP2 (Bacteroidia, Bacteroidetes)
Paludibacter propionicigenes WB4 (Bacteroidia, Bacteroidetes)
Marinilabilia salmonicolor JCM 21150 (Bacteroidia, Bacteroidetes)
Alistipes indistinctus YIT 12060 (Bacteroidia, Bacteroidetes)
Odoribacter laneus YIT 12061 (Bacteroidia, Bacteroidetes)
Candidatus Sulcia muelleri CARI (Flavobacteria, Bacteroidetes)
Candidatus Uzinura diaspidicola ASNER (Flavobacteria, Bacteroidetes)
Blattabacterium sp. Blatta orientalis Tarazona (Flavobacteria, Bacteroidetes)
Psychroflexus torquis ATCC 700755 (Flavobacteria, Bacteroidetes)
Capnocytophaga sp. oral taxon 335 F0486 (Flavobacteria, Bacteroidetes)
Nonlabens dokdonensis DSW-6 (Flavobacteria, Bacteroidetes)
Sphingobacterium spiritivorum ATCC 33300 (Sphingobacteria, Bacteroidetes)
Chitinophaga pinensis DSM 2588 (Sphingobacteria, Bacteroidetes)
Rhodothermus marinus SG0.5JP17-172 (Bacteroidetes)
Bacteroidetes
Gloeobacter violaceus PCC 7421 (Gloeobacteria, Cyanobacteria)
Richelia intracellularis HH01 (Nostocales, Cyanobacteria)
Paulinella chromatophora (Cercozoa, Rhizaria)
Synechococcus sp. RCC307 (Oscillatoriophycideae, Cyanobacteria)
Prochlorococcus marinus MIT 9211 (Prochlorales, Cyanobacteria)
Prochlorococcus marinus MIT 9515 (Prochlorales, Cyanobacteria)
Cyanobacteria
Cryptomonas paramecium (Cryptomonadales, Cryptophyta)
Cyanophora paradoxa (Cyanophoraceae, Glaucophyta)
Trifolium pratense (Streptophyta, Viridiplantae)
Lotus japonicus (Streptophyta, Viridiplantae)
Vitis vinifera (Streptophyta, Viridiplantae)
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Zea mays (Streptophyta, Viridiplantae)
Oryza sativa Japonica Group (Streptophyta, Viridiplantae)
Picea sitchensis (Streptophyta, Viridiplantae)
Physcomitrella patens patens (Streptophyta, Viridiplantae)
Selaginella moellendorffii (Streptophyta, Viridiplantae)
Chlamydomonas reinhardtii (Chlorophyta, Viridiplantae)
Bathycoccus prasinos (Chlorophyta, Viridiplantae)
Amphidinium carterae (Dinoflagellata, Alveolata)
Pavlova lutheri (Pavlovales, Haptophyta)
Heterosigma akashiwo (Raphidophyceae, Stramenopiles)
Durinskia baltica (Dinoflagellata, Alveolata)
Kryptoperidinium foliaceum (Dinoflagellata, Alveolata)
Thalassiosira pseudonana (Bacillariophyta, Stramenopiles)
Phaeodactylum tricornutum (Bacillariophyta, Stramenopiles)
Saccharina japonica (PXclade, Stramenopiles)
Vaucheria litorea (PXclade, Stramenopiles)
Galdieria sulphuraria (Bangiophyceae, Rhodophyta)
Gracilaria tenuistipitata liui (Florideophyceae, Rhodophyta)
Antithamnion sp. (Florideophyceae, Rhodophyta)
Chondrus crispus (Florideophyceae, Rhodophyta)
Calliarthron tuberculosum (Florideophyceae, Rhodophyta)
Porphyra purpurea (Bangiophyceae, Rhodophyta)
Rhodomonas salina (Pyrenomonadales, Cryptophyta)
Guillardia theta (Pyrenomonadales, Cryptophyta)
Cyanidium caldarium (Bangiophyceae, Rhodophyta)
Neospora caninum Liverpool (Apicomplexa, Alveolata)
Toxoplasma gondii GT1 (Apicomplexa, Alveolata)
Plasmodium falciparum 3D7 (Apicomplexa, Alveolata)
Bigelowiella natans (Cercozoa, Rhizaria)
Perkinsus marinus ATCC 50983 (Perkinsea, Alveolata)
plastid-containing eukaryotes
Mycoplasma penetrans HF-2 (Mollicutes, Tenericutes)
Spiroplasma melliferum KC3 (Mollicutes, Tenericutes)
Marinitoga piezophila KA3 (Thermotogales, Thermotogae)
Anaerobaculum hydrogeniformans ATCC BAA-1850 (Synergistia, Synergistetes)
Candidatus Nitrospira defluvii (Nitrospirales, Nitrospirae)
Spirochaeta smaragdinae DSM 11293 (Spirochaetales, Spirochaetes)
Halanaerobium praevalens DSM 2228 (Clostridia, Firmicutes)
Halothermothrix orenii H 168 (Clostridia, Firmicutes)
Methanopyrus kandleri AV19 (Methanopyri, Euryarchaeota)
Desulfurobacterium thermolithotrophum DSM 11699 (Aquificales, Aquificae)
Lachnospiraceae bacterium 1 4 56FAA (Clostridia, Firmicutes)
Desulfococcus oleovorans Hxd3 (Deltaproteobacteria, Proteobacteria)
Desulfomicrobium baculatum DSM 4028 (Deltaproteobacteria, Proteobacteria)
Syntrophomonas wolfei wolfei Goettingen (Clostridia, Firmicutes)
Ignisphaera aggregans DSM 17230 (Thermoprotei, Crenarchaeota)
Pyrobaculum neutrophilum V24Sta (Thermoprotei, Crenarchaeota)
Pyrolobus fumarii 1A (Thermoprotei, Crenarchaeota)
Hyperthermus butylicus DSM 5456 (Thermoprotei, Crenarchaeota)
Caminibacter mediatlanticus TB-2 (Epsilonproteobacteria, Proteobacteria)
Mahella australiensis 50-1 BON (Clostridia, Firmicutes)
Methanococcoides burtonii DSM 6242 (Methanomicrobia, Euryarchaeota)
Corynebacterium matruchotii ATCC 14266 (Actinobacteridae, Actinobacteria)
Sulfurovum sp. AR (Epsilonproteobacteria, Proteobacteria)
Candidatus Korarchaeum cryptofilum OPF8 (Korarchaeota)
Oscillibacter valericigenes Sjm18-20 (Clostridia, Firmicutes)
Archaeoglobus veneficus SNP6 (Archaeoglobi, Euryarchaeota)
Dictyoglomus turgidum DSM 6724 (Dictyoglomales, Dictyoglomi)
Desulfurococcus kamchatkensis 1221n (Thermoprotei, Crenarchaeota)
Thermofilum pendens Hrk 5 (Thermoprotei, Crenarchaeota)
Thermofilum pendens Hrk 5 (Thermoprotei, Crenarchaeota)
Desulfurococcus mucosus DSM 2162 (Thermoprotei, Crenarchaeota)
Fervidicoccus fontis Kam940 (Thermoprotei, Crenarchaeota)
Caldisphaera lagunensis DSM 15908 (Thermoprotei, Crenarchaeota)
Pyrobaculum aerophilum IM2 (Thermoprotei, Crenarchaeota)
Metallosphaera cuprina Ar-4 (Thermoprotei, Crenarchaeota)
Aciduliprofundum sp. MAR08-339 (Aciduliprofundum, Euryarchaeota)
Candidatus Arthromitus sp. SFB-rat-Yit (Clostridia, Firmicutes)
Anaerococcus vaginalis ATCC 51170 (Clostridia, Firmicutes)
Cryptobacterium curtum DSM 15641 (Coriobacteridae, Actinobacteria)
other Bacteria and Archaea
1
2
3

Topology	au	np	bp	pp	kh	sh	wkh	wsh
1	$3\cdot10^{-108}$	$3\cdot10^{-30}$	0	$1\cdot10^{-80}$	0	0	0	0
2	$1\cdot10^{-36}$	$7\cdot10^{-18}$	0	$2\cdot10^{-84}$	0	0	0	0
3	$3\cdot10^{-46}$	$3\cdot10^{-20}$	0	$2\cdot10^{-87}$	0	0	0	0

Ycf24



Algoriphagus sp. PR1 (Cytophagia, Bacteroidetes)
Cyclobacterium marinum DSM 745 (Cytophagia, Bacteroidetes)
Indibacter alkaliphilus LW1 (Cytophagia, Bacteroidetes)
Nitritalea halalkaliphila LW7 (Cytophagia, Bacteroidetes)
Belliella baltica DSM 15883 (Cytophagia, Bacteroidetes)
Mariniradius saccharolyticus AK6 (Cytophagia, Bacteroidetes)
Echinicola vietnamensis DSM 17526 (Cytophagia, Bacteroidetes)
Marinilabilia sp. AK2 (Bacteroidia, Bacteroidetes)
Cecembia lonarensis LW9 (Cytophagia, Bacteroidetes)
Fulvivirga imtechensis AK7 (Cytophagia, Bacteroidetes)
Marivirga tractuosa DSM 4126 (Cytophagia, Bacteroidetes)
Ceratium horridum (Dinoflagellata, Alveolata)
Candidatus Amoebophilus asiaticus 5a2 (Bacteroidetes)
Cardinium endosymbiont cEper1 of Encarsia pergandiella (Bacteroidetes)
Flexibacter litoralis DSM 6794 (Cytophagia, Bacteroidetes)
Cesiribacter andamanensis AMV16 (Cytophagia, Bacteroidetes)
Microscilla marina ATCC 23134 (Cytophagia, Bacteroidetes)
Cytophaga hutchinsonii ATCC 33406 (Cytophagia, Bacteroidetes)
Runella slithyformis DSM 19594 (Cytophagia, Bacteroidetes)
Fibrisoma limi BUZ 3 (Cytophagia, Bacteroidetes)
Emticicia oligotrophica DSM 17448 (Cytophagia, Bacteroidetes)
Leadbetterella byssophila DSM 17132 (Cytophagia, Bacteroidetes)
Pedobacter heparinus DSM 2366 (Sphingobacteria, Bacteroidetes)
Niabella soli DSM 19437 (Sphingobacteria, Bacteroidetes)
Porphyromonas gingivalis W83 (Bacteroidia, Bacteroidetes)
Tannerella forsythia ATCC 43037 (Bacteroidia, Bacteroidetes)
Candidatus Azobacteroides pseudotrichonymphae CFP2 (Bacteroidia, Bacteroidetes)
Dysgonomonas mossii DSM 22836 (Bacteroidia, Bacteroidetes)
Odoribacter laneus YIT 12061 (Bacteroidia, Bacteroidetes)
Alistipes indistinctus YIT 12060 (Bacteroidia, Bacteroidetes)
Paludibacter propionicigenes WB4 (Bacteroidia, Bacteroidetes)
Bacteroides coprosuis DSM 18011 (Bacteroidia, Bacteroidetes)
Anaerophaga sp. HS1 (Bacteroidia, Bacteroidetes)
Solitalea canadensis DSM 3403 (Sphingobacteria, Bacteroidetes)
Sphingobacterium spiritivorum ATCC 33300 (Sphingobacteria, Bacteroidetes)
Rhodothermus marinus DSM 4252 (Bacteroidetes)
Salinibacter ruber DSM 13855 (Bacteroidetes)
Blattabacterium sp. Periplaneta americana BPLAN (Flavobacteria, Bacteroidetes)
Candidatus Sulcia muelleri CARI (Flavobacteria, Bacteroidetes)
Capnocytophaga sp. CM59 (Flavobacteria, Bacteroidetes)
Croceibacter atlanticus HTCC2559 (Flavobacteria, Bacteroidetes)
Fluviicola taffensis DSM 16823 (Flavobacteria, Bacteroidetes)
Bacteroidetes
Gloeobacter violaceus PCC 7421 (Gloeobacteria, Cyanobacteria)
Paulinella chromatophora (Cercozoa, Rhizaria)
Synechococcus sp. RCC307 (Oscillatoriophycideae, Cyanobacteria)
Prochlorococcus marinus marinus CCMP1375 (Prochlorales, Cyanobacteria)
cyanobacterium UCYN-A (Oscillatoriophycideae, Cyanobacteria)
Leptolyngbya sp. PCC 7375 (Oscillatoriophycideae, Cyanobacteria)
Cyanobacteria
Aureoumbra lagunensis (Pelagophyceae, Stramenopiles)
Cyanophora paradoxa (Cyanophoraceae, Glaucophyta)
Guillardia theta (Pyrenomonadales, Cryptophyta)
Cryptomonas paramecium (Cryptomonadales, Cryptophyta)
Rhodomonas salina (Pyrenomonadales, Cryptophyta)
Porphyra umbilicalis (Bangiophyceae, Rhodophyta)
Galdieria sulphuraria (Bangiophyceae, Rhodophyta)
Calliarthron tuberculosum (Florideophyceae, Rhodophyta)
Phaeocystis antarctica (Phaeocystales, Haptophyta)
Emiliania huxleyi (Isochrysidales, Haptophyta)
Thalassiosira pseudonana (Bacillariophyta, Stramenopiles)
Phaeodactylum tricornutum (Bacillariophyta, Stramenopiles)
Kryptoperidinium foliaceum (Dinoflagellata, Alveolata)
Durinskia baltica (Dinoflagellata, Alveolata)
Heterosigma akashiwo (Raphidophyceae, Stramenopiles)
Saccharina japonica (PXclade, Stramenopiles)
Vaucheria litorea (PXclade, Stramenopiles)
Pavlova lutheri (Pavlovales, Haptophyta)
Cyanidium caldarium (Bangiophyceae, Rhodophyta)
Nannochloropsis gaditana (Eustigmatophyceae, Stramenopiles)
Chromerida sp. RM11 (Chromerida, Alveolata)
Plasmodium falciparum (Apicomplexa, Alveolata)
Toxoplasma gondii RH (Apicomplexa, Alveolata)
Eimeria tenella strain Penn State (Apicomplexa, Alveolata)
Arabidopsis thaliana (Streptophyta, Viridiplantae)
Vitis vinifera (Streptophyta, Viridiplantae)
Oryza sativa Japonica Group (Streptophyta, Viridiplantae)
Selaginella moellendorffii (Streptophyta, Viridiplantae)
Physcomitrella patens patens (Streptophyta, Viridiplantae)
Volvox carteri f. nagariensis (Chlorophyta, Viridiplantae)
Micromonas pusilla CCMP1545 (Chlorophyta, Viridiplantae)
Coccomyxa subellipsoidea C-169 (Chlorophyta, Viridiplantae)
Chlorella variabilis (Chlorophyta, Viridiplantae)
Bigelowiella natans (Cercozoa, Rhizaria)
Gymnochlora stellata (Cercozoa, Rhizaria)
plastid-containing eukaryotes
①
②
Helcococcus kunzii ATCC 51366 (Clostridia, Firmicutes)
Peptoniphilus lacrimalis 315-B (Clostridia, Firmicutes)
Anaerococcus vaginalis ATCC 51170 (Clostridia, Firmicutes)
Dialister invisus DSM 15470 (Negativicutes, Firmicutes)
Selenomonas sp. oral taxon 149 67H29BP (Negativicutes, Firmicutes)
Collinsella intestinalis DSM 13280 (Coriobacteridae, Actinobacteria)
Candidatus Arthromitus sp. SFB-rat-Yit (Clostridia, Firmicutes)
Streptobacillus moniliformis DSM 12112 (Fusobacteriales, Fusobacteria)
Thermoanaerobacterium thermosaccharolyticum DSM 571 (Clostridia, Firmicutes)
Fervidobacterium pennivorans DSM 9078 (Thermotogales, Thermotogae)
Mesotoga prima MesG1.Ag.4.2 (Thermotogales, Thermotogae)
Halomicrobium mukohataei DSM 12286 (Halobacteria, Euryarchaeota)
Staphylothermus hellenicus DSM 12710 (Thermoprotei, Crenarchaeota)
Thermosphaera aggregans DSM 11486 (Thermoprotei, Crenarchaeota)
Acidilobus saccharovorans 345-15 (Thermoprotei, Crenarchaeota)
Thermococcus sibiricus MM 739 (Thermococci, Euryarchaeota)
Aeropyrum pernix K1 (Thermoprotei, Crenarchaeota)
Metallosphaera cuprina Ar-4 (Thermoprotei, Crenarchaeota)
Thermofilum pendens Hrk 5 (Thermoprotei, Crenarchaeota)
Fervidicoccus fontis Kam940 (Thermoprotei, Crenarchaeota)
Thermoproteus tenax Kra 1 (Thermoprotei, Crenarchaeota)
Caldivirga maquilingensis IC-167 (Thermoprotei, Crenarchaeota)
Thermoplasma acidophilum DSM 1728 (Thermoplasmata, Euryarchaeota)
Deinococcus deserti VCD115 (Deinococci, Deinococcus-Thermus)
Ktedonobacter racemifer DSM 44963 (Ktedonobacteria, Chloroflexi)
Mycoplasma gallisepticum NY01 2001.047-5-1P (Mollicutes, Tenericutes)
Spiroplasma citri (Mollicutes, Tenericutes)
Clostridiales genomosp. BVAB3 UPII9-5 (Clostridia, Firmicutes)
Eggerthia catenaformis OT 569 DSM 20559 (Erysipelotrichi, Firmicutes)
Acholeplasma laidlawii PG-8A (Mollicutes, Tenericutes)
Gemella sanguinis M325 (Bacilli, Firmicutes)
Leuconostoc mesenteroides cremoris ATCC 19254 (Bacilli, Firmicutes)
Weissella thailandensis fsh4-2 (Bacilli, Firmicutes)
Catellicoccus marimammalium M35/04/3 (Bacilli, Firmicutes)
Facklamia hominis CCUG 36813 (Bacilli, Firmicutes)
Streptococcus sanguinis SK160 (Bacilli, Firmicutes)
Sulfobacillus acidophilus TPY (Clostridia, Firmicutes)
Propionibacterium acnes J165 (Actinobacteridae, Actinobacteria)
Spirochaeta africana DSM 8902 (Spirochaetales, Spirochaetes)
Candidatus Micrarchaeum acidiphilum ARMAN-2 (Euryarchaeota)
Verrucomicrobiae bacterium DG1235 (Verrucomicrobiae, Verrucomicrobia)
Leptospira meyeri Semaranga Veldrot Semarang 173 (Spirochaetales, Spirochaetes)
Candidatus Portiera aleyrodidarum BT-B-HRs (Gammaproteobacteria, Proteobacteria)
other Bacteria and Archaea

Topology	au	np	bp	pp	kh	sh	wkh	wsh
1	$3\cdot10^{-55}$	$7\cdot10^{-22}$	0	$2\cdot10^{-90}$	0	0	0	0
2	$7\cdot10^{-102}$	$3\cdot10^{-29}$	0	$5\cdot10^{-97}$	0	0	0	0