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Phylogeny and species delimitation in the lichen genus *Cetrelia*

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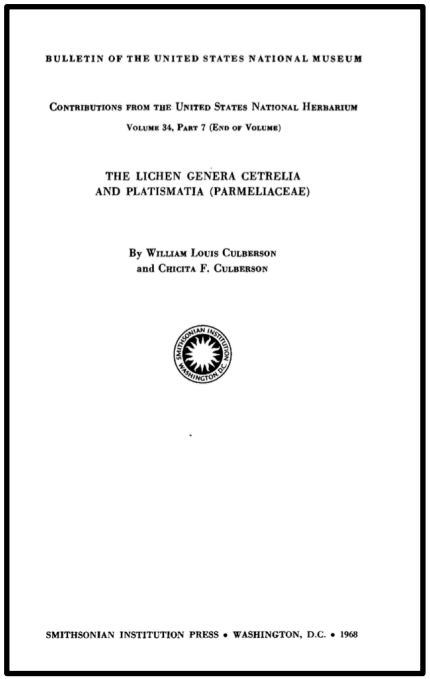
Cetrelia W.L. Culb. & C.F. Culb.

- Described by the Culbersons in 1968
- Some species from *Cetraria* and *Parmelia* were combined into 2 new genera, *Cetrelia* and *Platismatia*
- Based mainly on chemical characters, correlated with some visible morphological and anatomical traits



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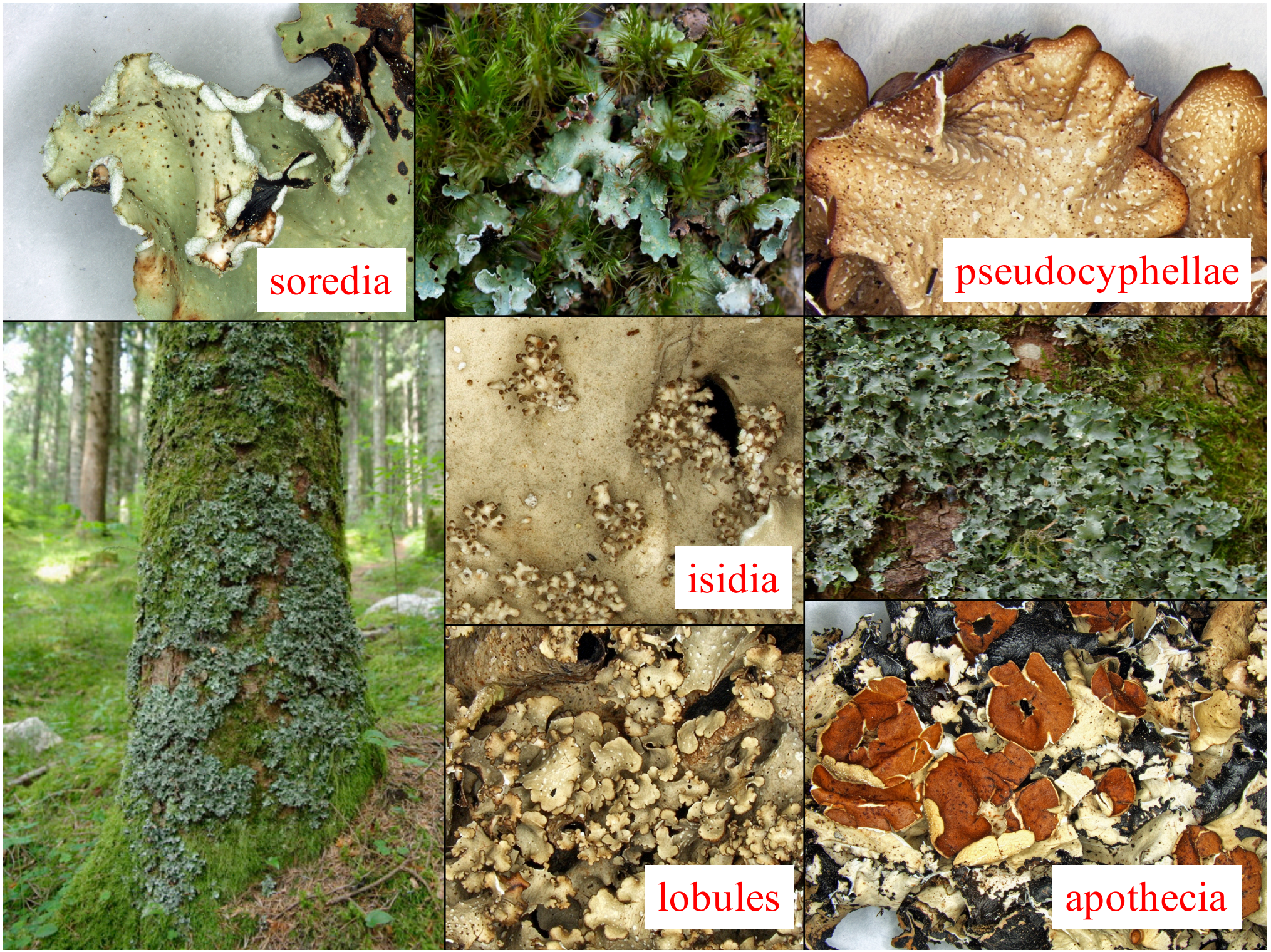
THE LICHEN GENERA CETRELIA
AND PLATISMATIA (PARMELIACEAE)

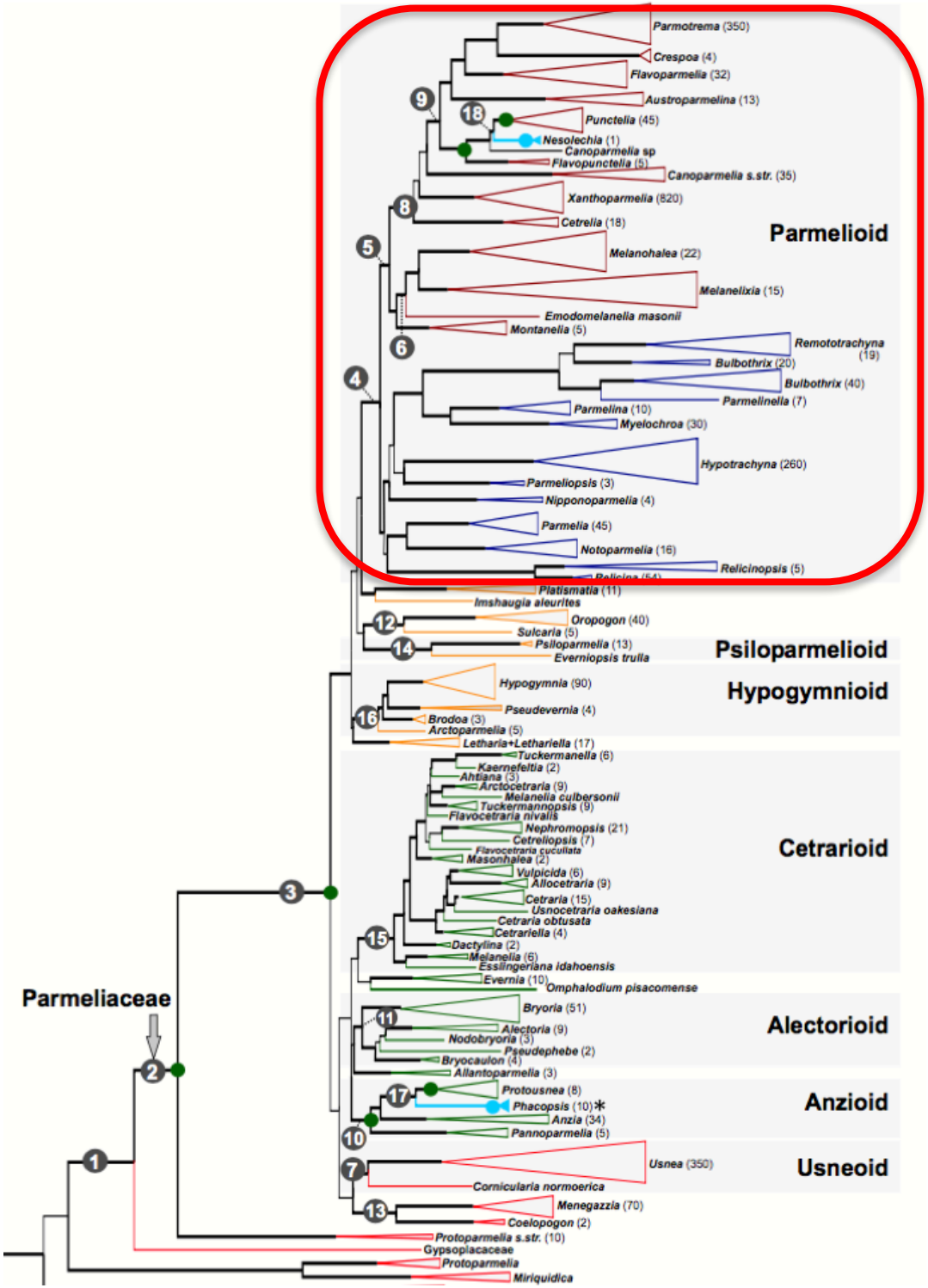
By WILLIAM LOUIS CULBERSON
and CHICITA F. CULBERSON

SMITHSONIAN INSTITUTION PRESS • WASHINGTON, D.C. • 1968

Characters of the genus

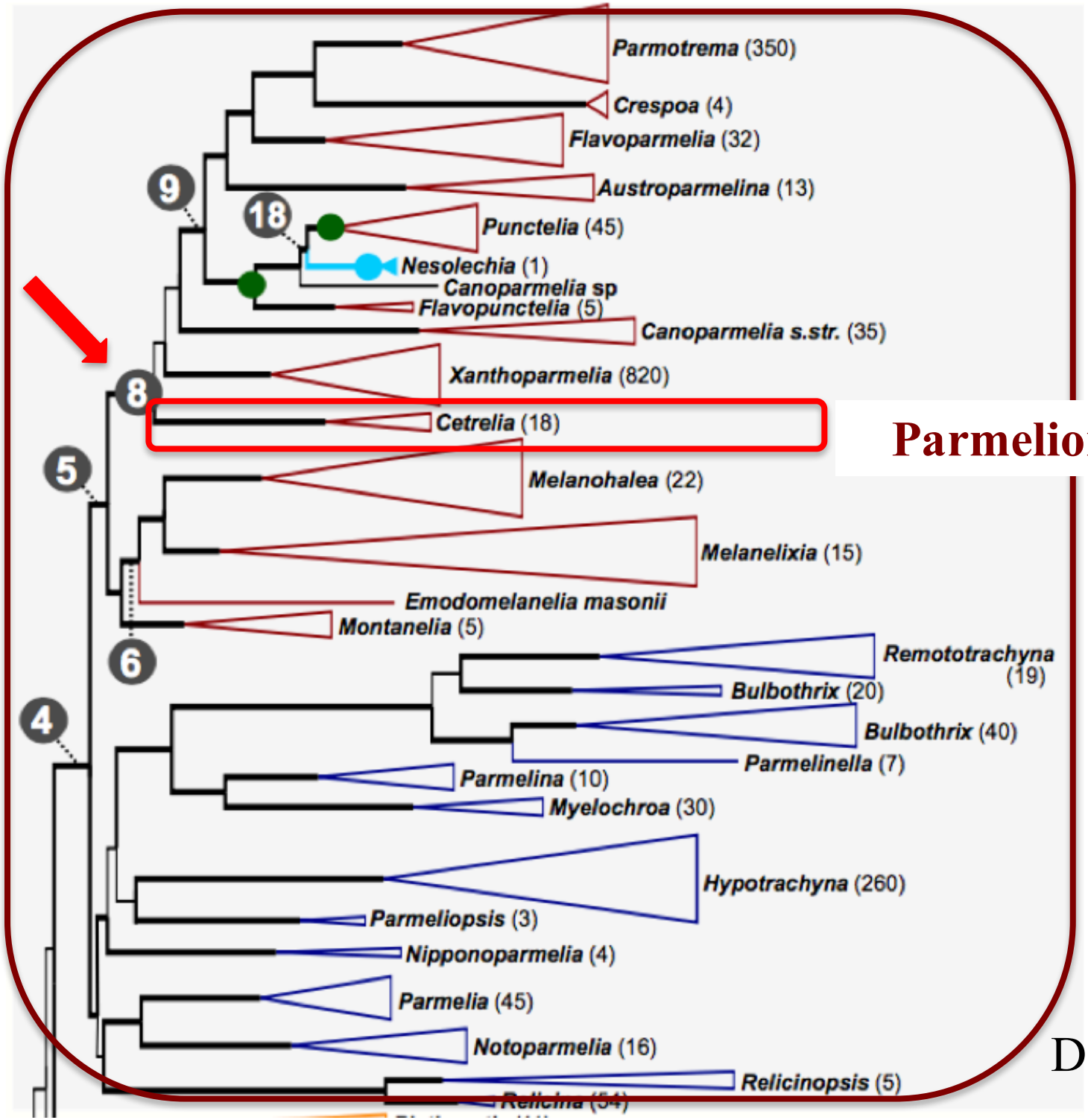
- Foliose, greenish-grey thallus with broad rounded lobes
- Pseudocyphellae on the upper surface
- Some species with structures of vegetative reproduction (soredia, isidia & lobules), others reproduce sexually
- Atranorin in the cortex, various orcinol depsides and depsidones in the medulla
- Distribution centre in the eastern and southeastern Asia


soredia
pseudocyphellae
isidia
lobules
apothecia



Position within the family Parmeliaceae

Divakar et al. 2015



Parmelioid clade

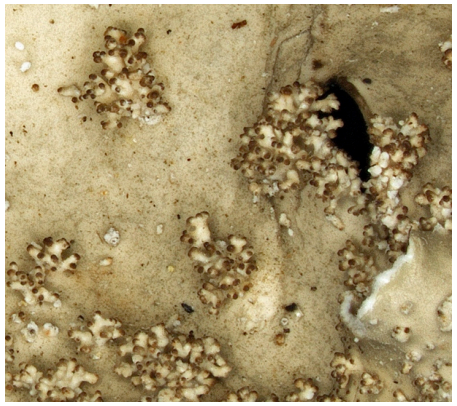
Divakar et al. 2015

Delimitation of species

- Includes 18 species – IF chemical species concept is accepted
- Species are delimited as combinations of morpho- and chemotypes
- Samples of different chemotypes, although morphologically almost uniform, are considered as distinct species

Morphotypes (3)

- With vegetative propagules:
  - sorediate (1)
  - isidiate/lobulate (2)
- Without vegetative propagules, often with apothecia (3)

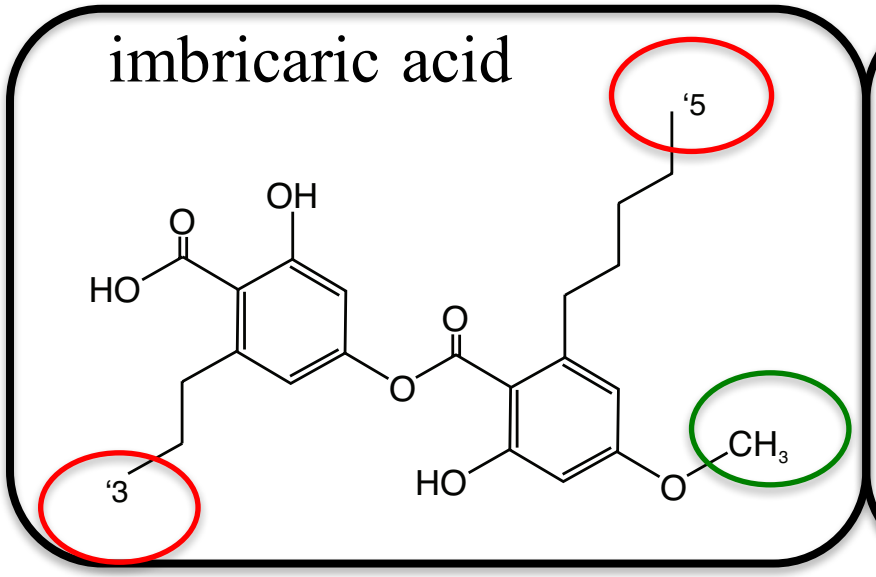


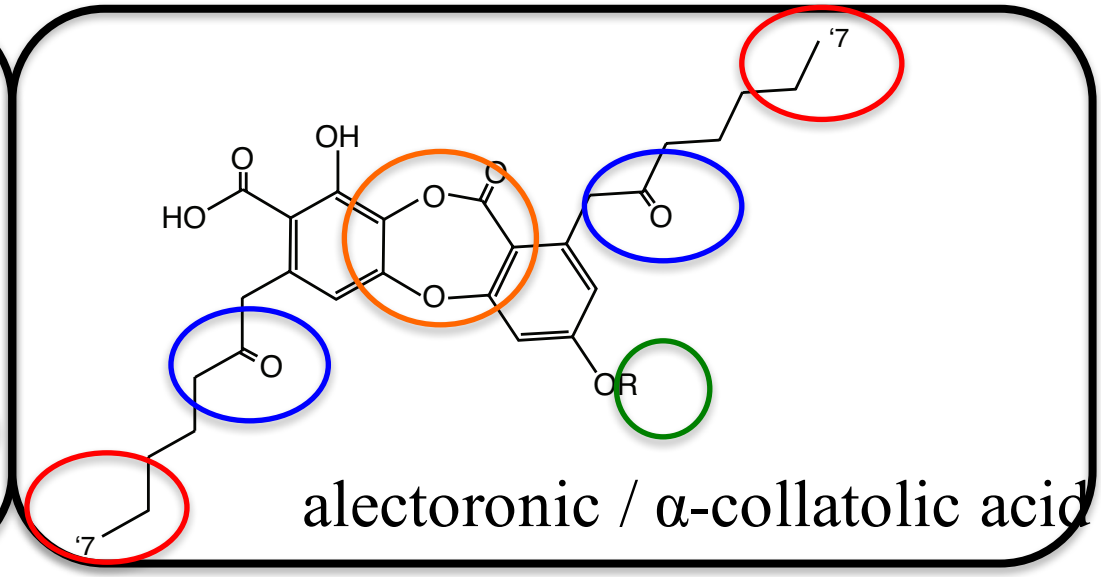
Chemosyndromic variation

- … is a situation where species produce not a few medullary compounds but a set of biochemically related major and minor products
- Chemotypes are identified according to 1-2 major medullary substances
- In addition, up to 7 minor compounds may be present in one *Cetrelia* species
- The same compound can be a major product in one, and minor product in another taxon

Chemotypes (6)

Major substances	**Imbrica-ric**	**Olivetoric**	**Anziaic**	**Perlatolic**	**Micro-phyllinic**	**Alectoronic + α-collatolic**
Side chain lengths	3+5	5+7	5+5	5+5	7+7	7+7
Side chain oxydation	no	1 chain	no	no	both chains	both chains
Oxydative cyclization	no – depside	no – depside	no – depside	no – depside	no – depside	yes – depsidones
O-methyl.	CH_3	H	H	CH_3	CH_3	R= H – alector. R= CH_3 – α-coll.





The *Cetrelia olivetorum* complex

- ... is best known, most widely distributed, and taxonomically the most discussed
- Represents sorediate morphotype
- 5 species are known in the complex:
  - *Cetrelia cetrarioides*
  - *C. chicitae*
  - *C. monachorum*
  - *C. olivetorum*
  - *C. sayanensis*

The *Cetrelia olivetorum* complex

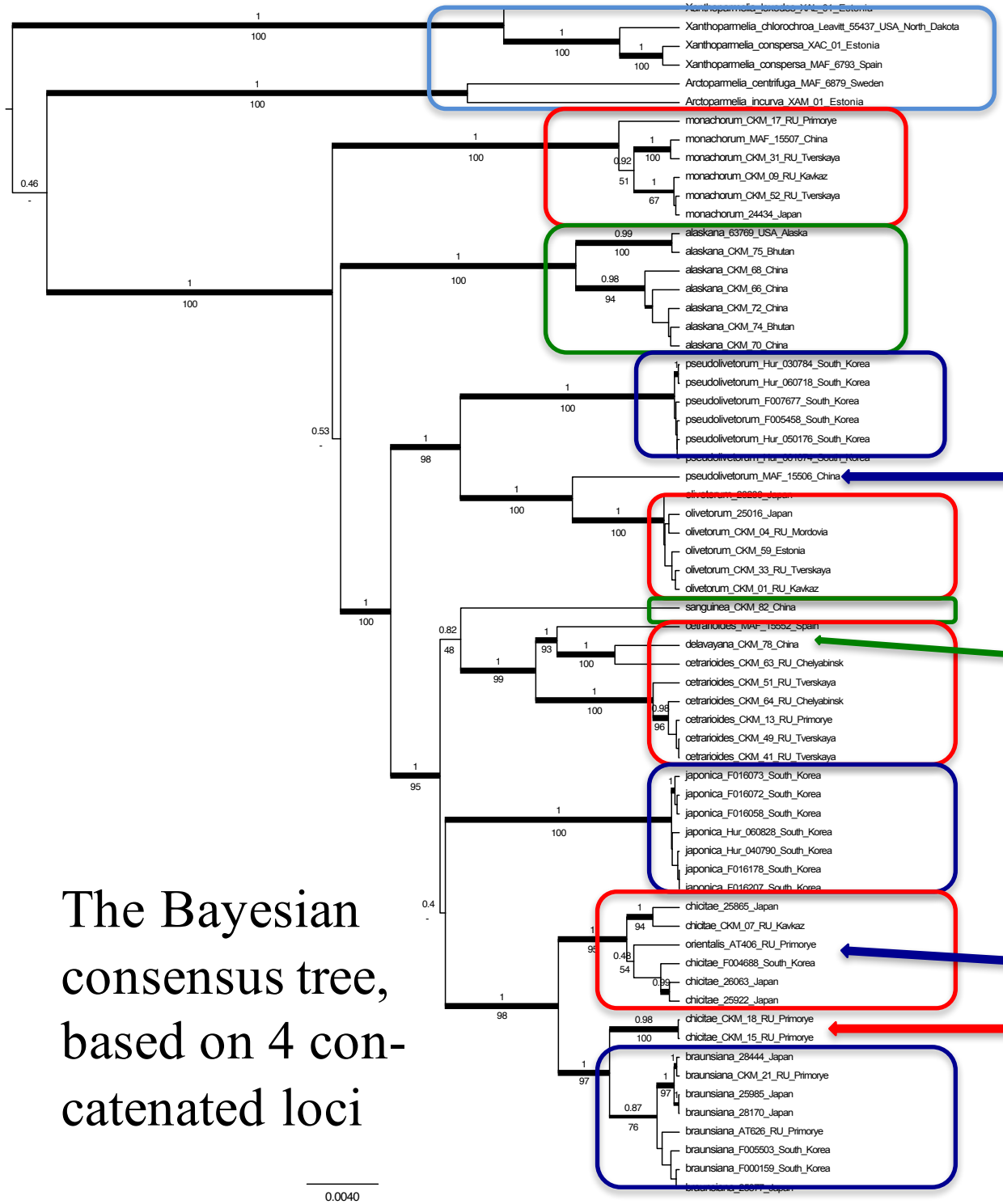
- Morphology and chemistry of this complex was investigated in detail by Obermayer and Mayrhofer (2007) based on material from Alps
- Minute morphological differences concerning pseudocyphellae and soredia were noticed between the samples from different chemotypes
- **What about the phylogenetic relationships?**

Aims of our study

- To clarify the species concept in *Cetrelia* through molecular phylogenetic analyses:
  - Is the treatement of taxa of the same morphotype but different chemotypes as one species phylogenetically acceptable?
  - Is the theory by Culbersons (1976) that chemical evolution in *Cetrelia* was directed towards shorter side chains of orcinol compounds reliable?

Material & Methods

- 58 samples representing 11 species, all 6 chemotypes and all reproductive structures
- 4 molecular markers – ITS, IGS, MCM7, RPB1
- Maximum likelihood (ML) single-locus trees using the RAxML
- ML and Bayesian concatenated analyses using RAxML and BEAST



The Bayesian consensus tree, based on 4 concatenated loci

outgroup

sorediate

without veget. struct.

lobulate

lobulate

sorediate

without veget. struct.

without veget. struct.

sorediate

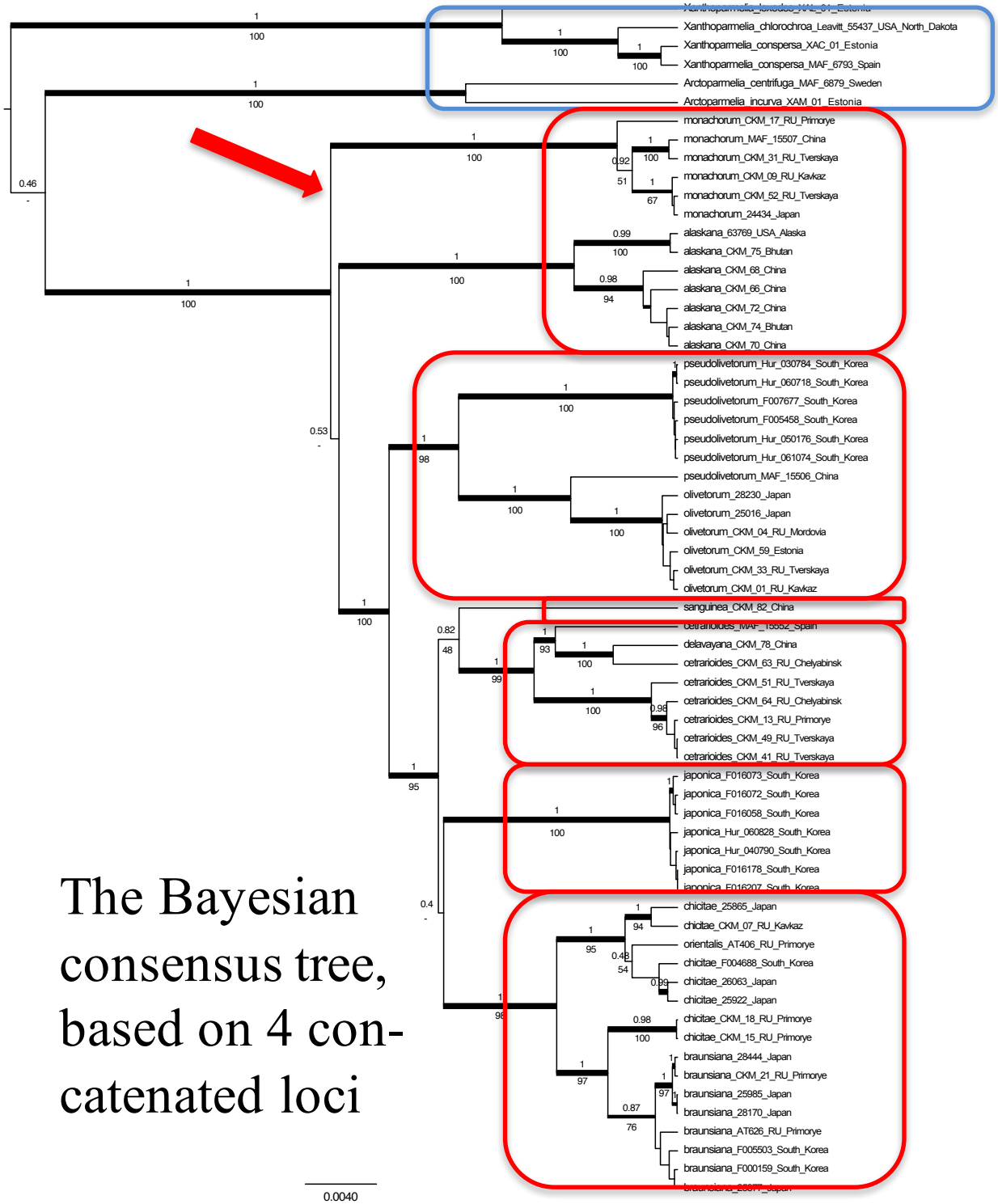
lobulate

sorediate

lobulate

sorediate

isidiate



The Bayesian consensus tree, based on 4 con-catenated loci

outgroup

imbricaric acid

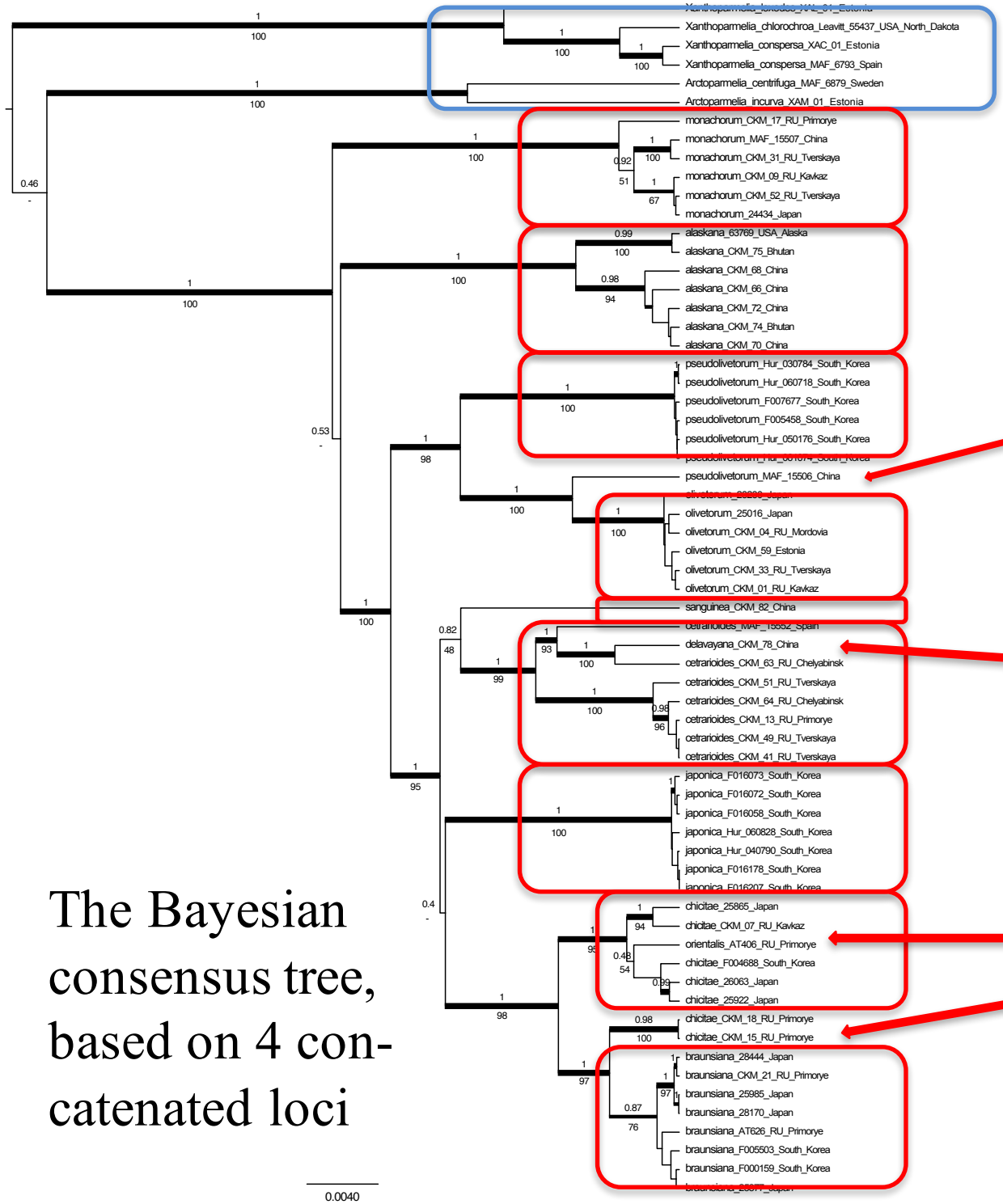
olivetoric acid

anziaic acid

perlatolic acid

microphyllinic acid

alectoronic + α-collatolic acids



The Bayesian consensus tree, based on 4 concatenated loci

outgroup

C. monachorum

C. alaskana

C. pseudolivetorum !

C. olivetorum

C. sanguinea

C. delavayana

C. cetrarioides !

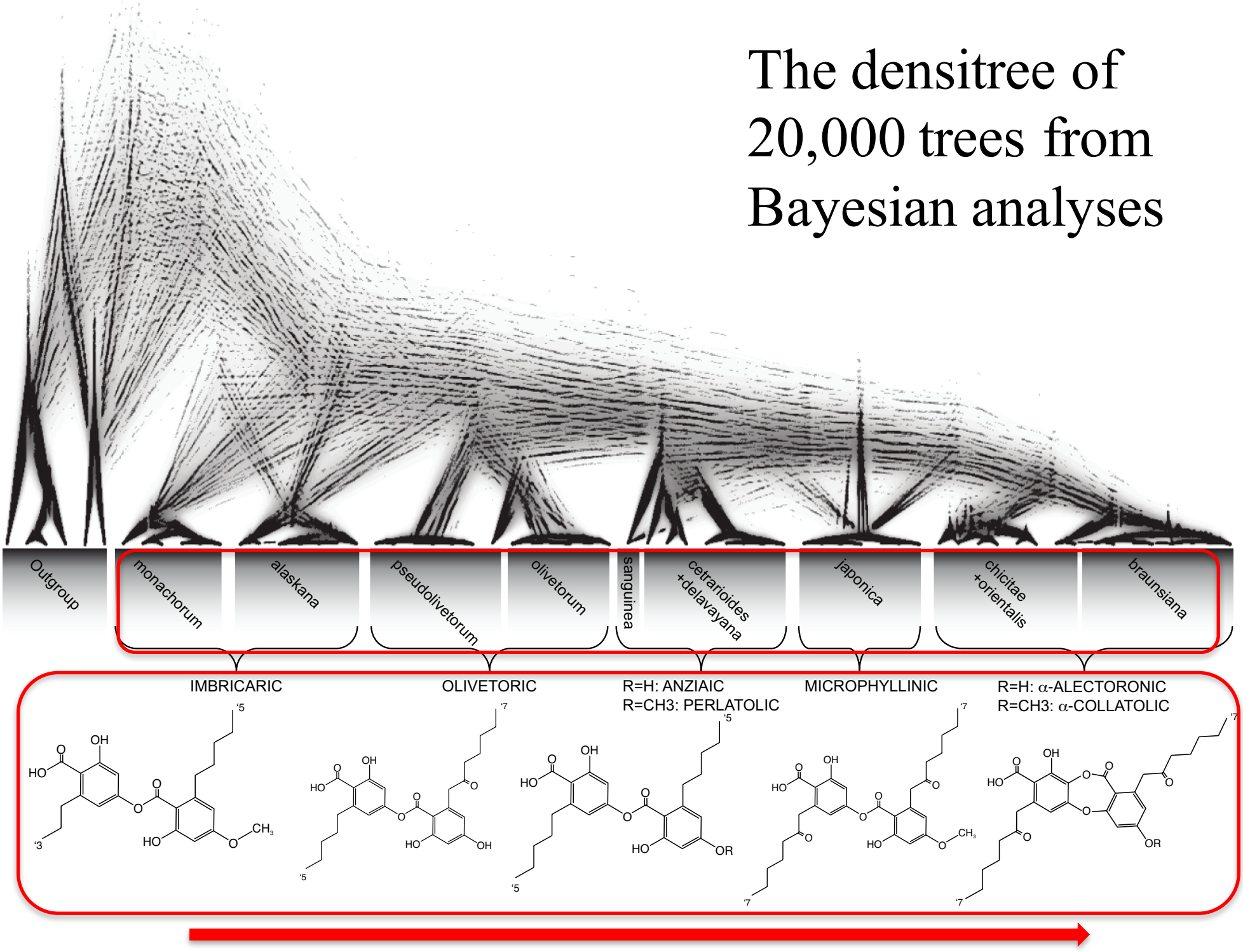
C. japonica

C. orientalis

C. chicitae !

C. braunsiana

The densitree of 20,000 trees from Bayesian analyses



Conclusions 1

- Sec. chemistry clearly correlates with molec. phylogeny in *Cetrelia*, morphology does not
- Chemotypes form monophyletic clades that include subclades generally correlating with morphotypes → chemical evolution in *Cetrelia* occurred before diversification of morphotypes
- The direction of chemical evolution in *Cetrelia* is towards more complex substances, not towards shorter side chains

Conclusions 2

- The chemical species concept should be accepted in *Cetrelia*
- The species can be treated as combinations of a chemotype and a morphotype
- Samples of the same morphotype but different chemotype should be recognized as distinct species

Identification key for *Cetrelia* species (18)

MORPHOTYPES (3)	CHEMOTYPES (6)					
	Imbricaric	Olivetoric	Anziaic	Perlatolic	Microphyllinic	Alectoronic + α-collatolic
Sorediate	***C. monachorum*** soralia labriform, soredia coarse ***C. sayanensis*** soralia labriform to pustulate-capitate, soredia fine	***C. olivetorum*** soralia labriform, soredia fine	?	***C. cetrarioides*** soralia labriform, soredia fine	?	***C. chicitae*** soralia labriform, soredia coarse
Isidiate and/or lobulate	***C. sinensis*** lobulae palmately divided	***C. pseud-olivetorum*** lobulae multibranched	***C. isidiata*** isidia globose to slightly branched and coralloid	?	***C. japonica*** lobulae multibranched	***C. braunsiana*** isidia granular to coralloid ***C. orientalis*** lobulae palmately divided
Without vegetative propagules	***C. collata*** apothecia frequent, pseudocyphellae large ***C. alaskana*** apothecia rare, pseudocyphellae small	***C. davidiana*** apothecia frequent, pseudocyphellae small	***C. sanguinea*** apothecia frequent, pseudocyphellae small	***C. delavayana*** apothecia frequent, pseudocyphellae small	***C. pseudo-collata*** apothecia frequent, pseudocyphellae large	***C. nuda*** apothecia frequent, pseudocyphellae large

Conclusions 2

- The chemical species concept should be accepted in *Cetrelia*
- The species can be treated as combinations of a chemotype and a morphotype
- Samples of the same morphotype but different chemotype should be recognized as distinct species
- Chemically different sorediate species *C. cetrarioides, C. chicitae, C. monachorum* and *C. olivetorum* should not be considered as one!

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Thank you for the attention!