



Bamboo Evolution and Classification: Recent Advances

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U.S.A.**

Major Topics

- **Bamboos are grasses!**
- **Bamboo evolution and classification—updates**
- **Current directions**

A photograph of a dense thicket of bamboo and other grasses. The bamboo stalks are prominent, with some showing signs of aging or damage. The leaves are long and narrow, some green and some brown. The overall appearance is that of a wild, overgrown area. The text "Bamboos are grasses!" is overlaid in the center of the image.

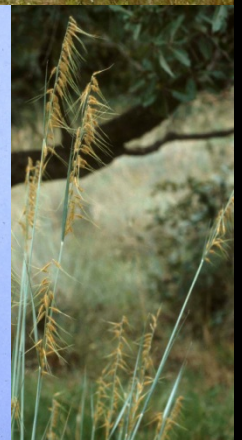
Bamboos are grasses!



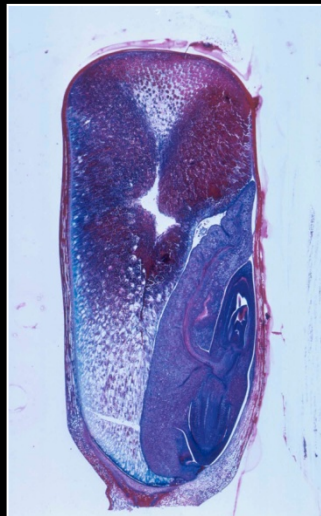
theclde, Flickr



L Attigala



What makes a grass a grass?

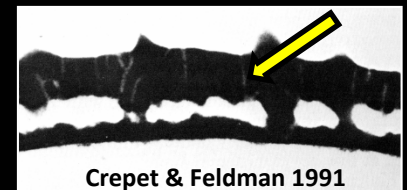


Grass-type embryo in lateral position and caryopsis fruit type



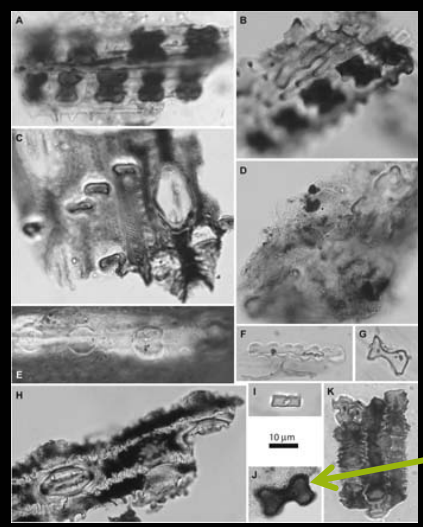
trnT inversion in the LSC region of the chloroplast

Micro-canals in the tectum



Origin of the
grasses
70-80 mya
in forests
of the S
hemisphere

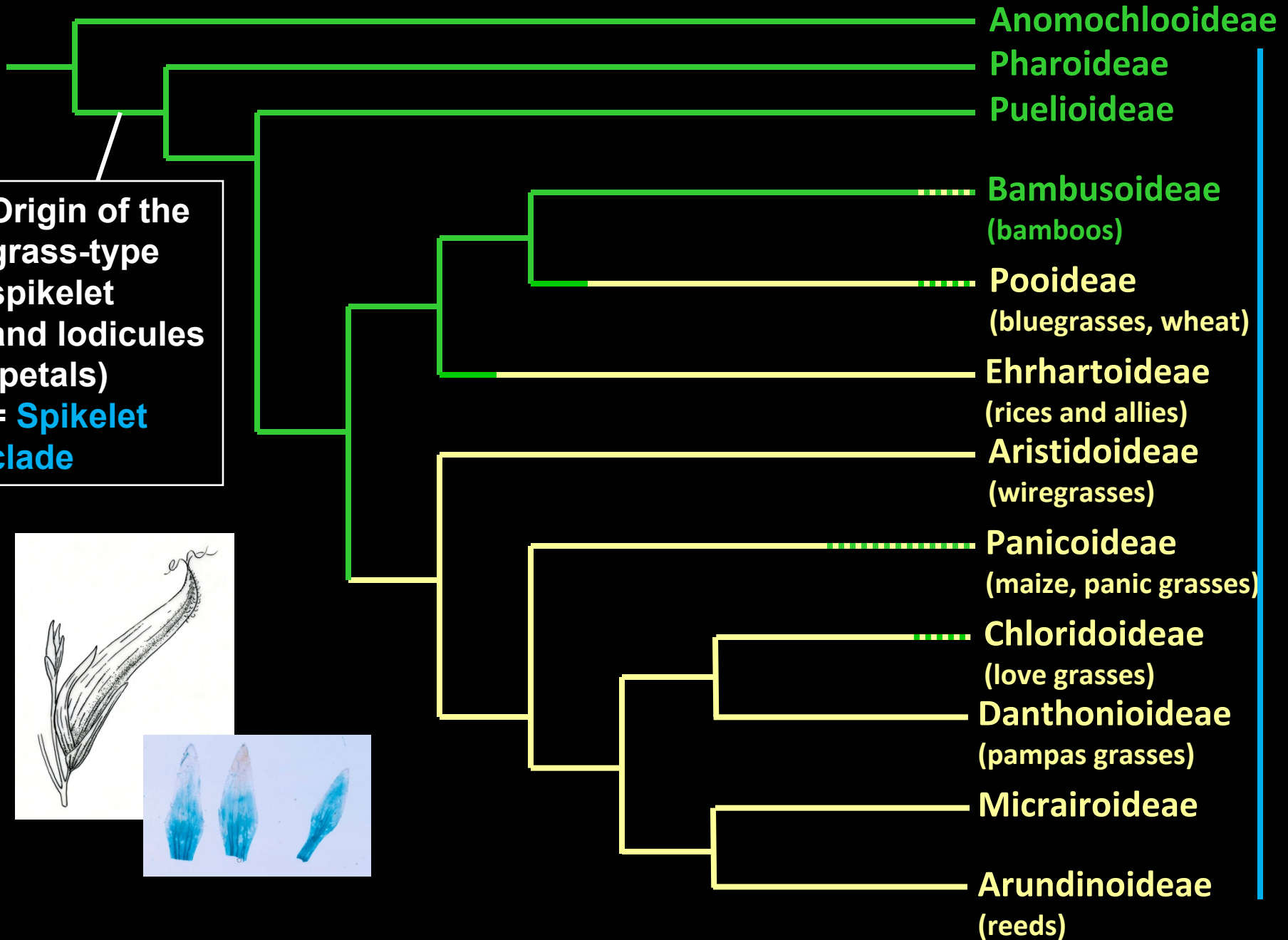
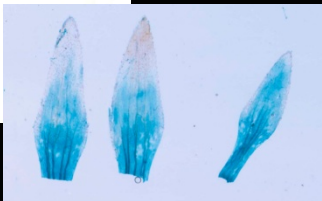
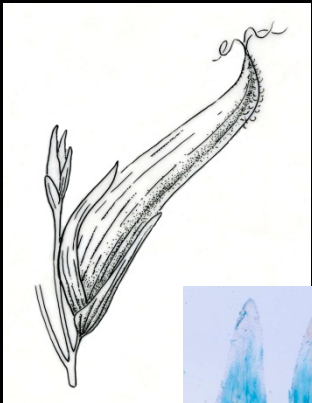
Ancestral
grasses

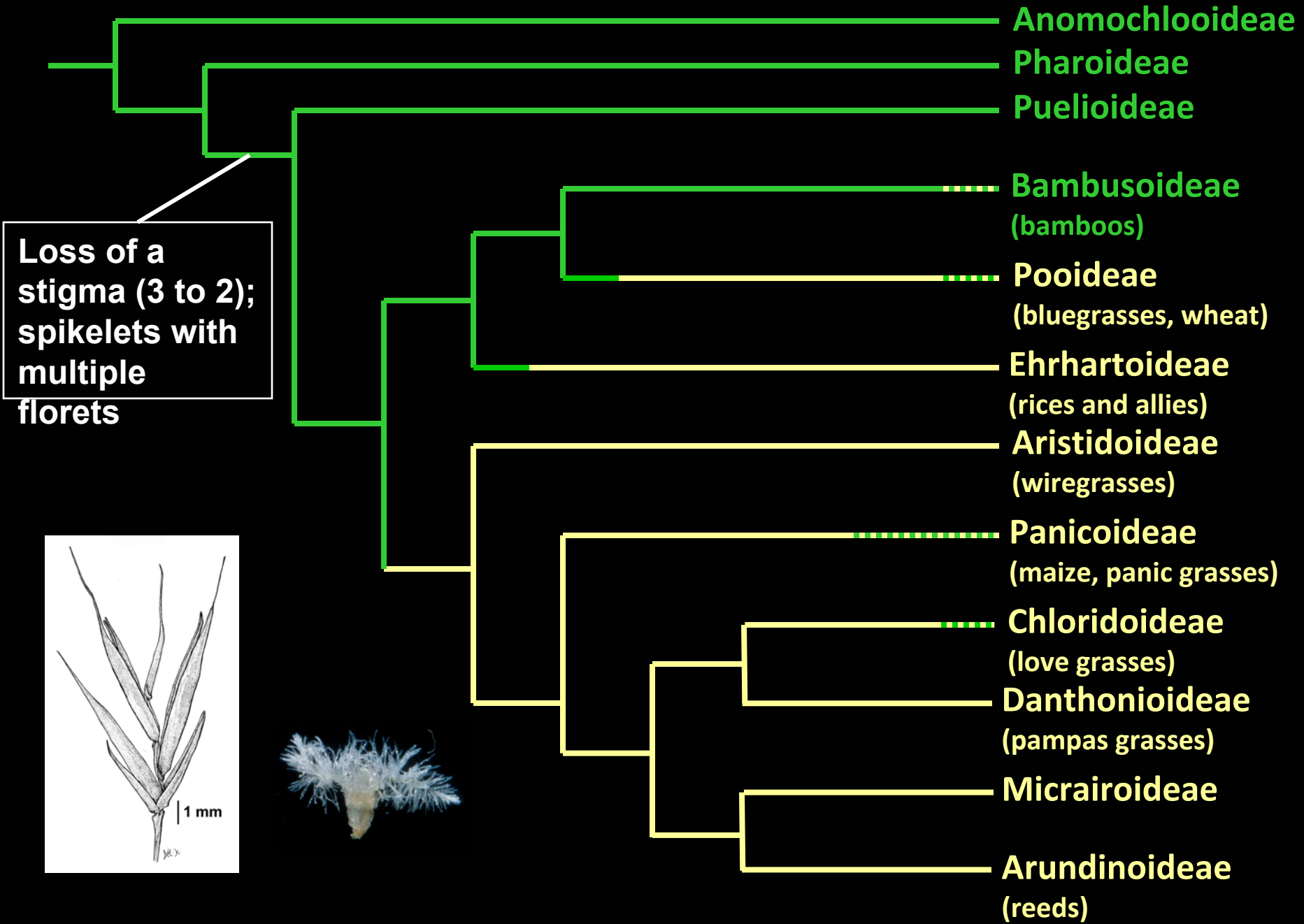


Silica bodies
(phytoliths)

Prasad et al. 2005

Origin of the
grass-type
spikelet
and lodicules
(petals)
= **Spikelet
clade**

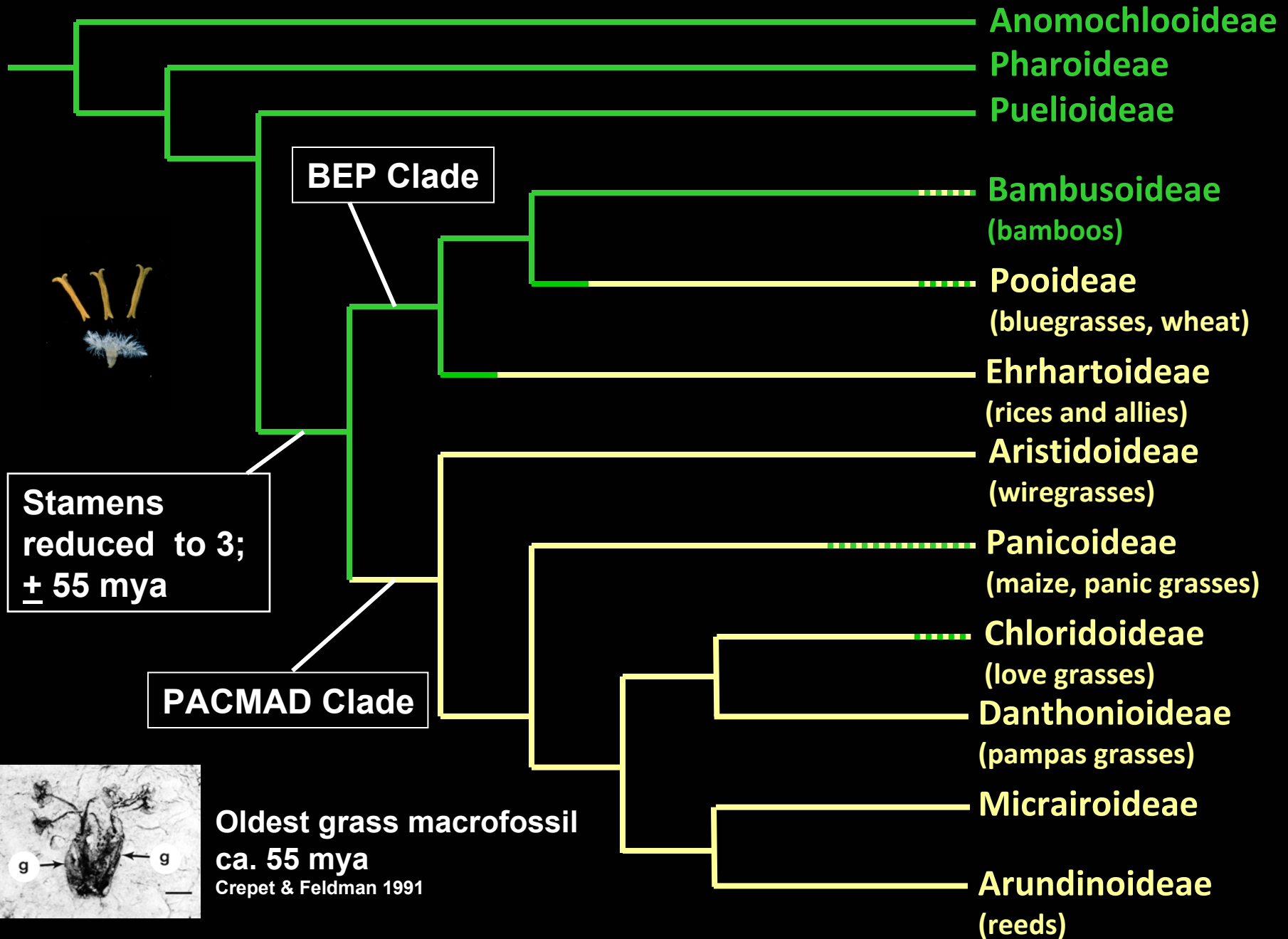


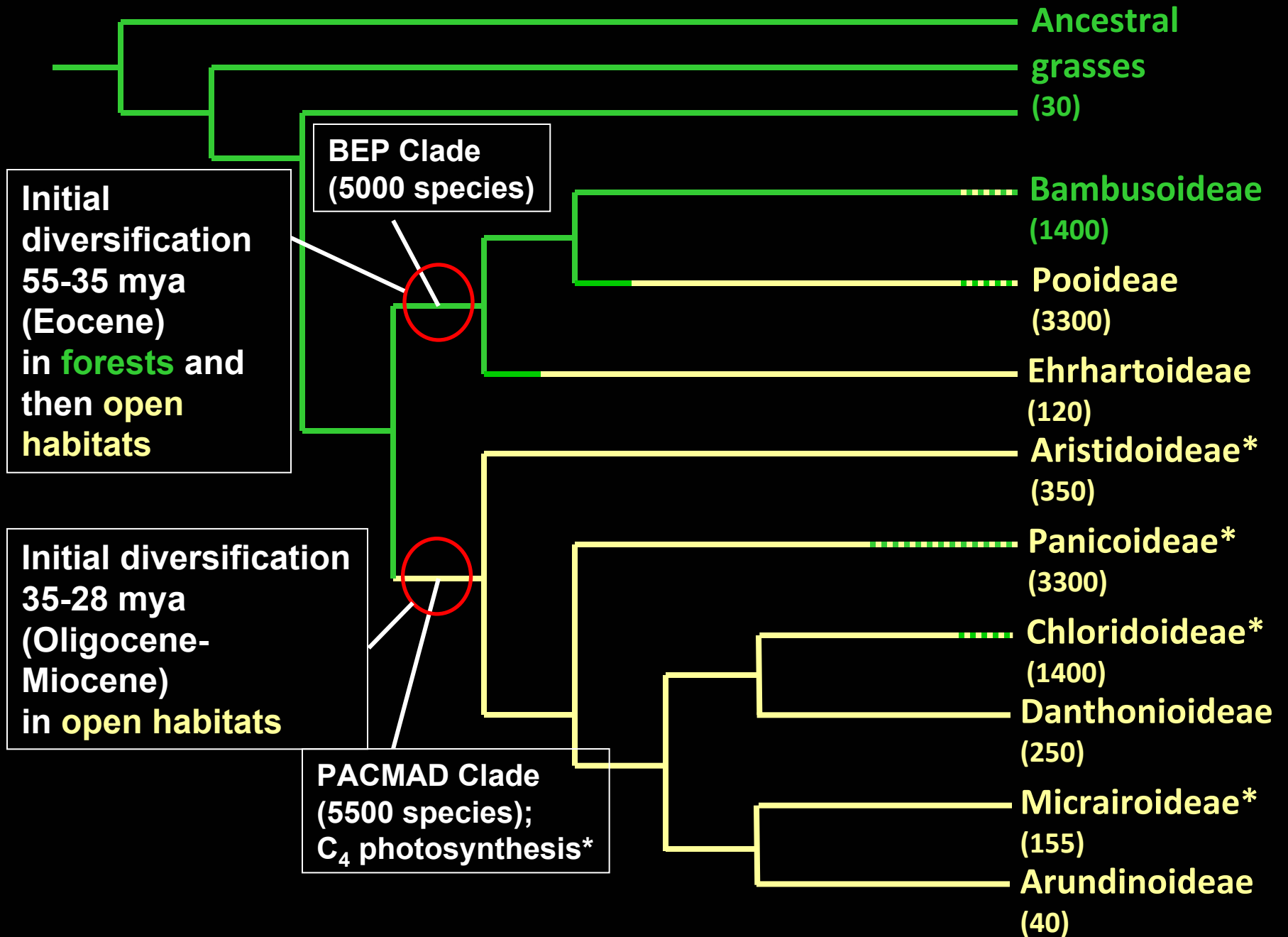


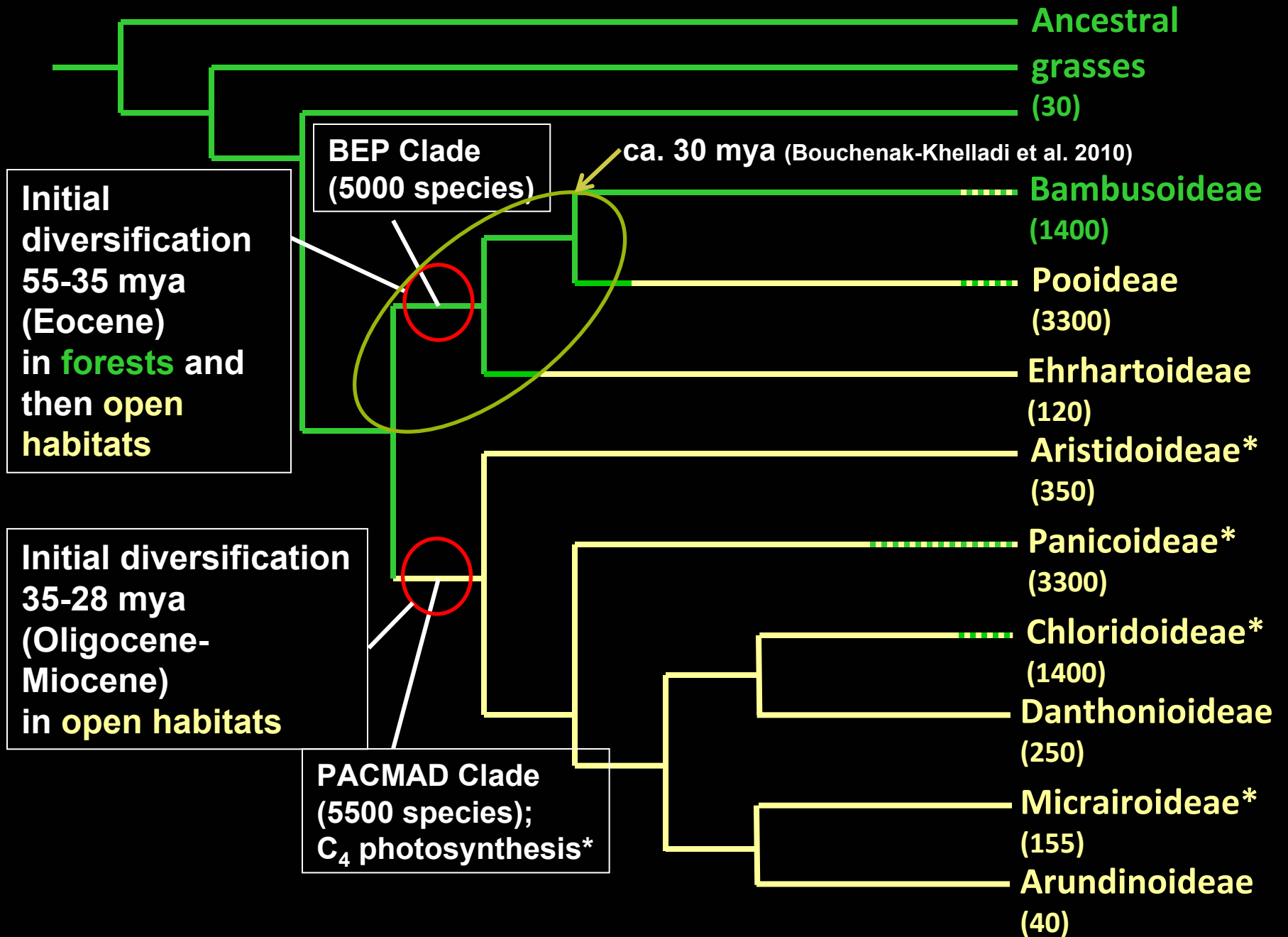
Ancestral or early-diverging grasses

(Anomochlooideae, Pharoideae, Puelioideae)

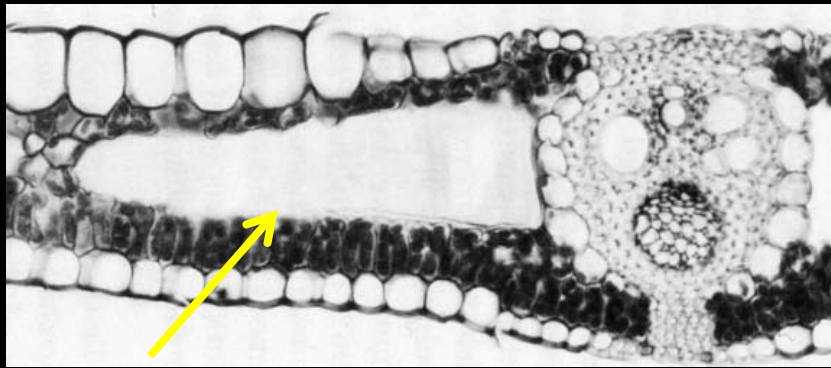




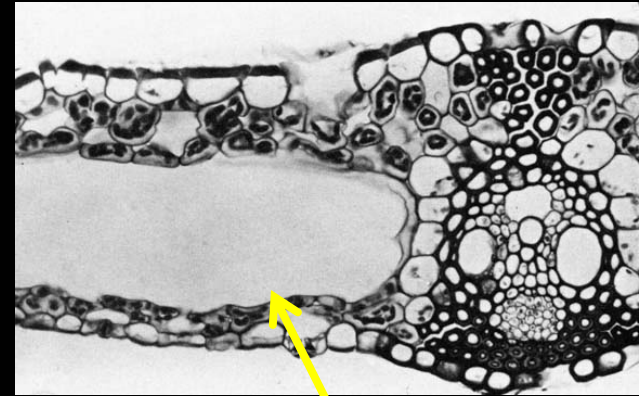




Pharoideae

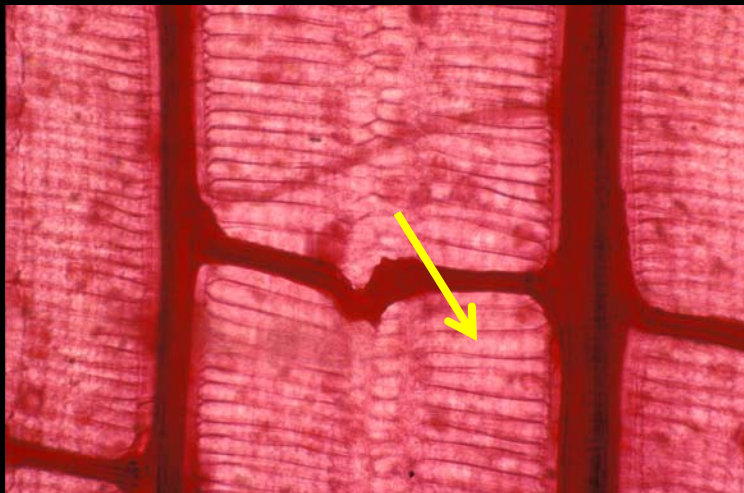


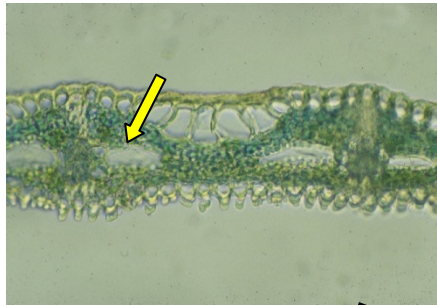
Anomochlooideae



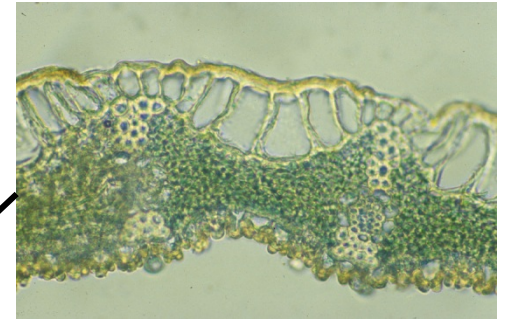
fusoid cell

Bambusoideae

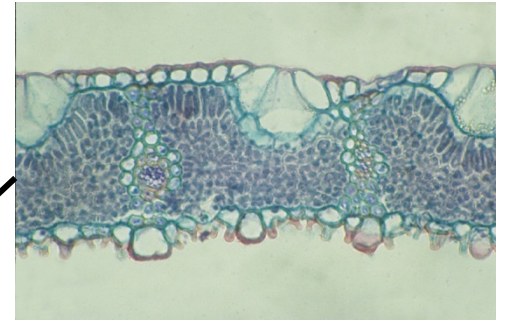




Y. niitakayamensis



C. culeou

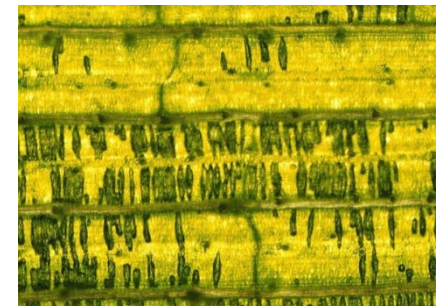


P. aurea

SHADE

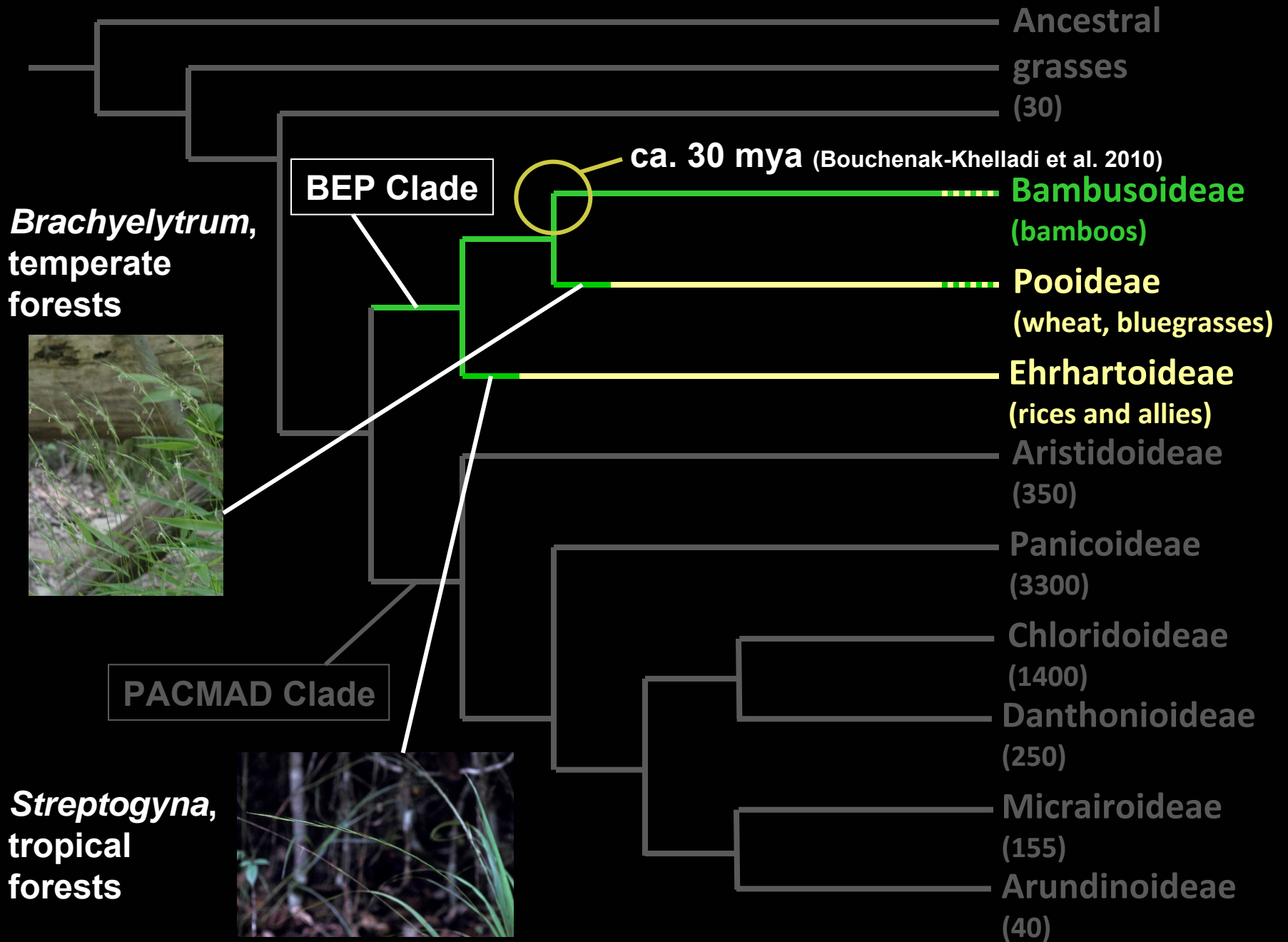
SUN

2 cm





Olyra ciliatifolia in the forest understory



A photograph of a dense thicket of bamboo and other grasses. The plants are green and brown, with some bamboo culms visible. The text is overlaid on the image.

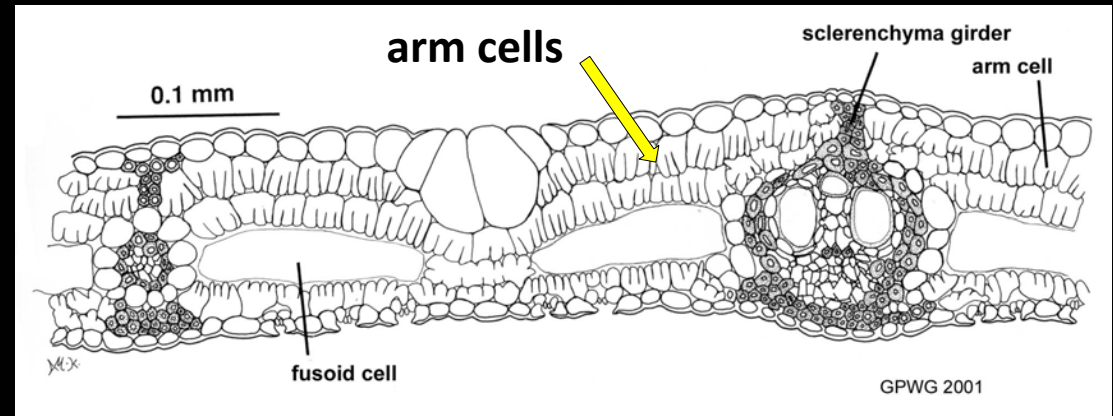
Bamboo evolution and classification —updates

Bamboos (subf. Bambusoideae)

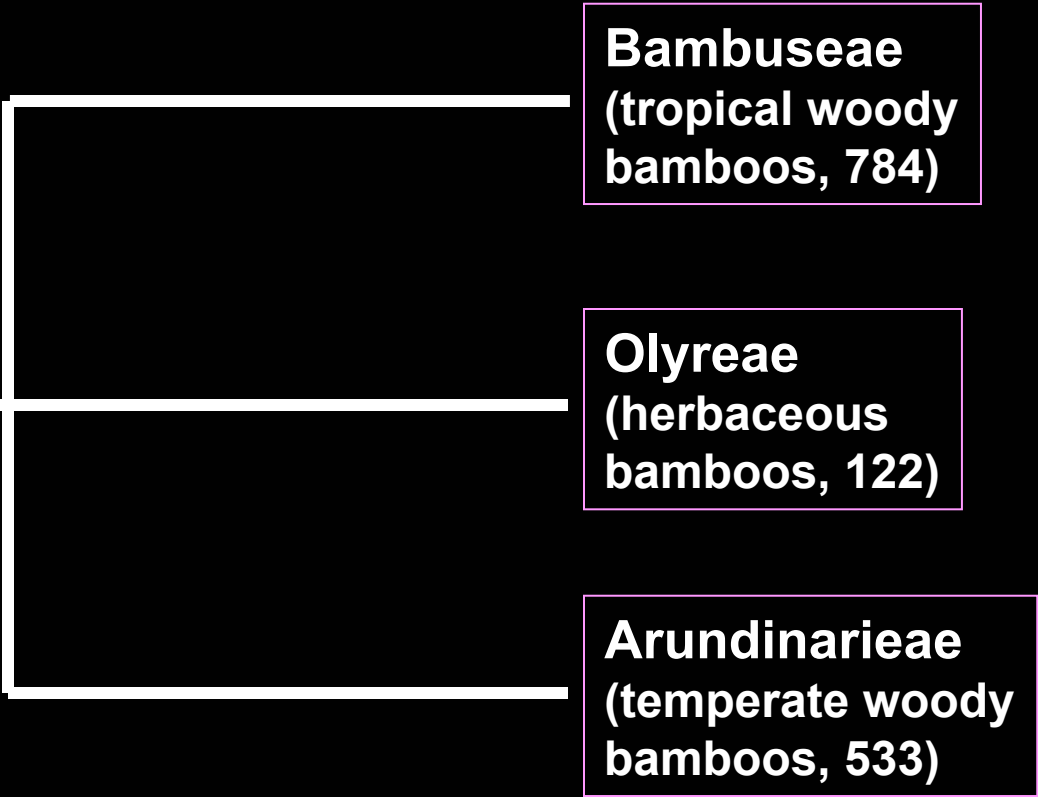
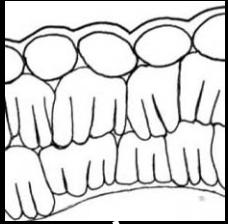
(>1,400 species)



X Londoño



The only major grass lineage to diversify in forests

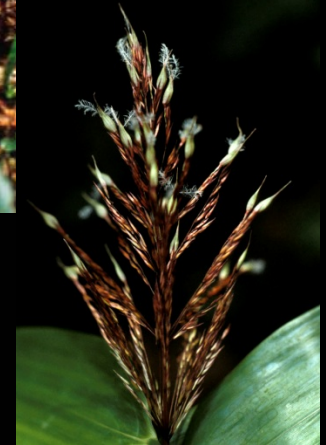


Three principal lineages of Bamusoideae

Olyreae—herbaceous bamboos



Patricia
de Oliveira

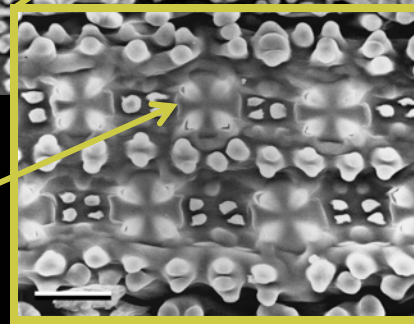
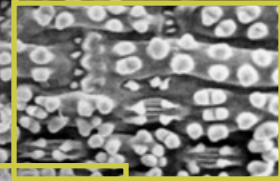
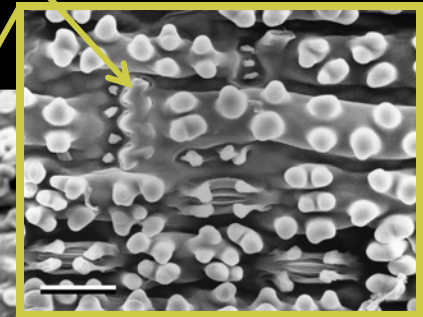
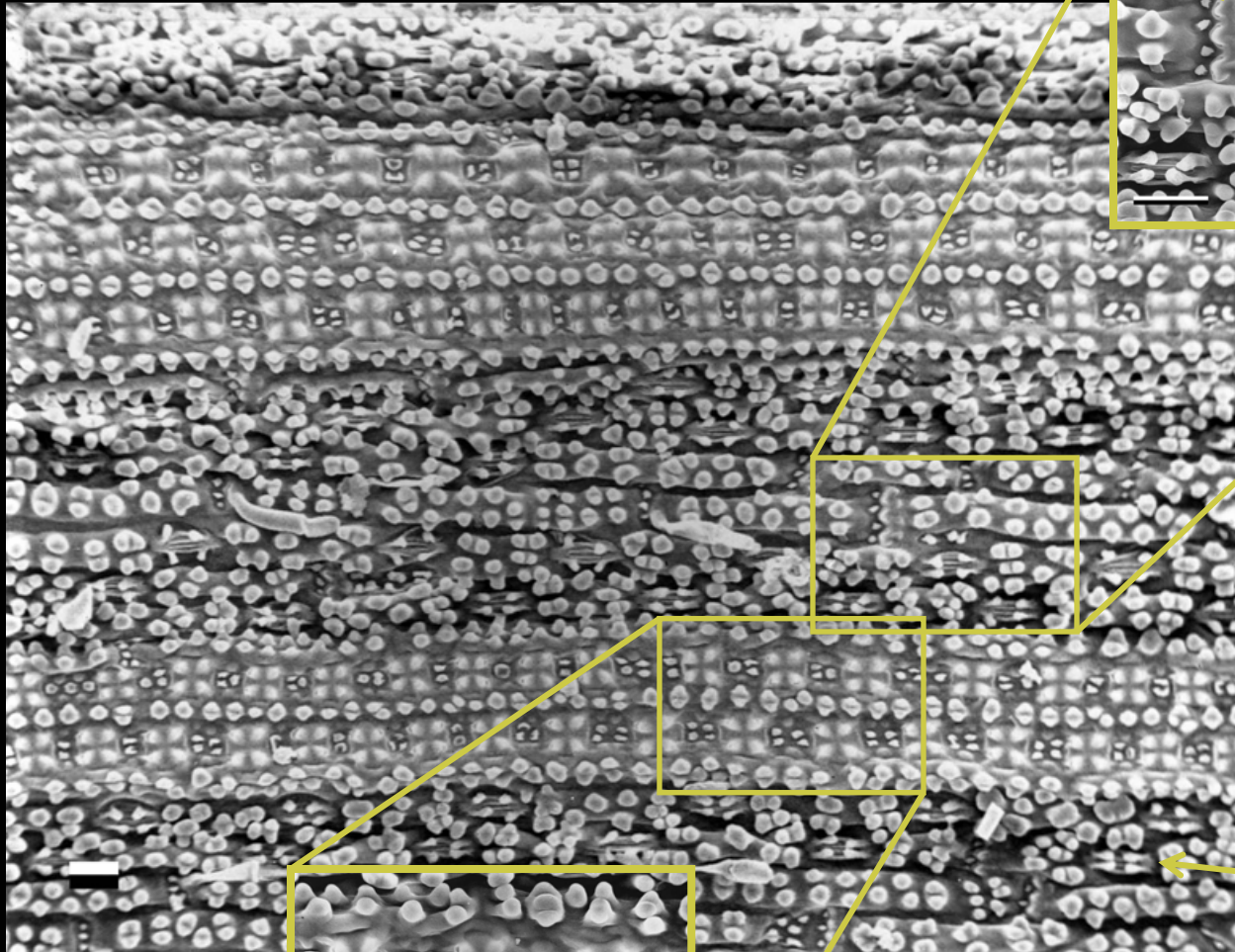


**21 genera, ca. 122 described species,
primarily Latin American**

Olyreae, lower leaf surface

crenate (olyroid)
silica body

veins



cruciform
silica body

stomate

Olyreae have unisexual spikelets and unusual adaptations in some



Olyra standleyi

gregarious monocarpy



Eremitis

underground spikelets



Pariana

insect pollination?

*Raddiella
vanessae*,
smallest
bamboo

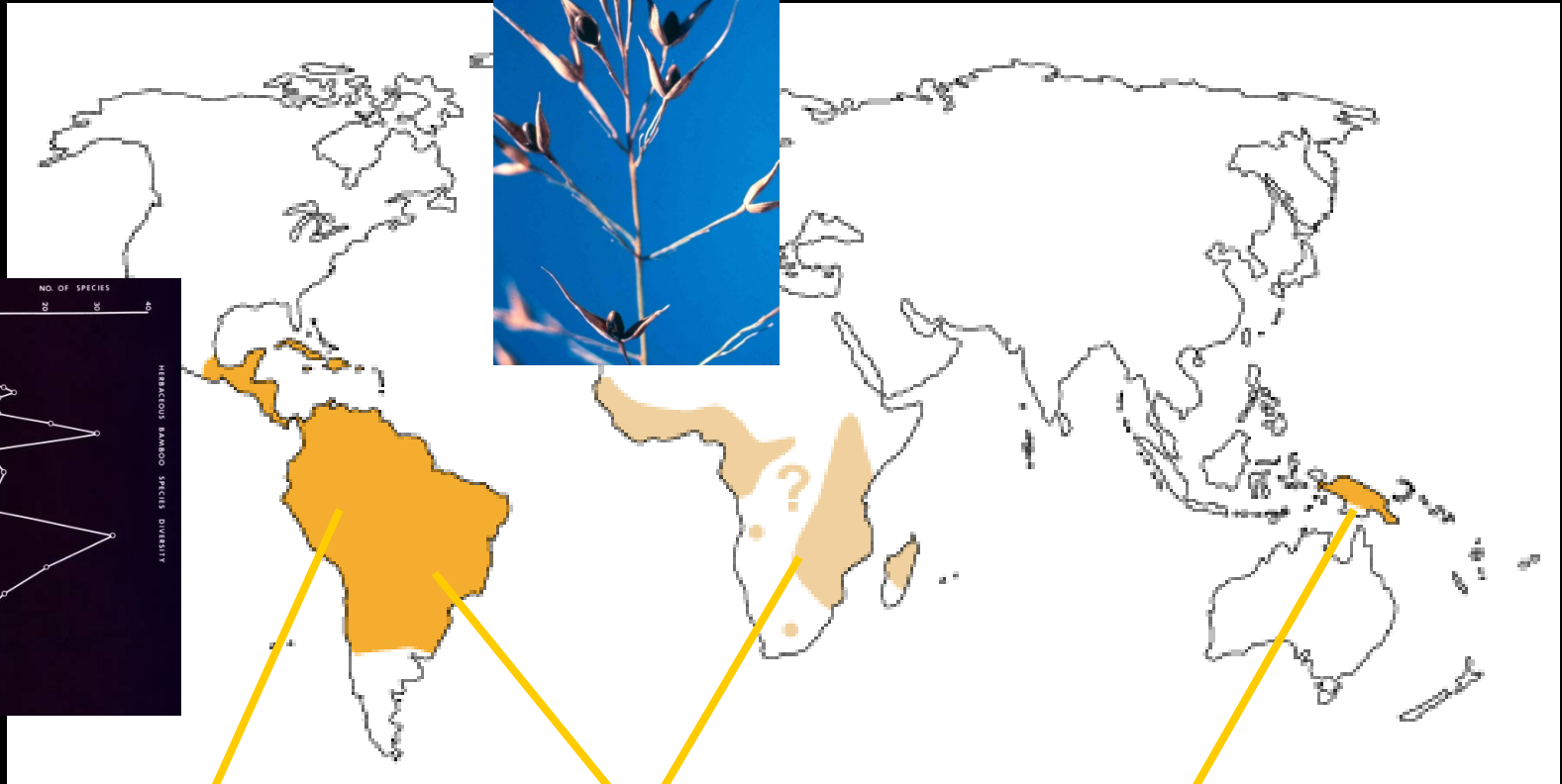
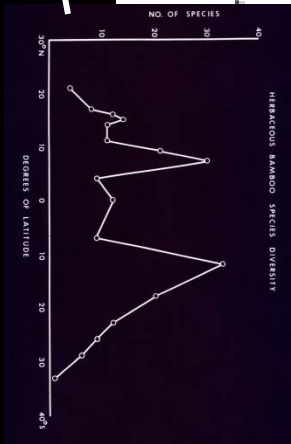


Diandrolyra

“hidden”
inflorescences

Olyreae distribution

Latitudinal diversity



rest of tribe

Olyra latifolia

Buergersiochloa (1 species)

Arundinarieae (temperate woody bamboos)



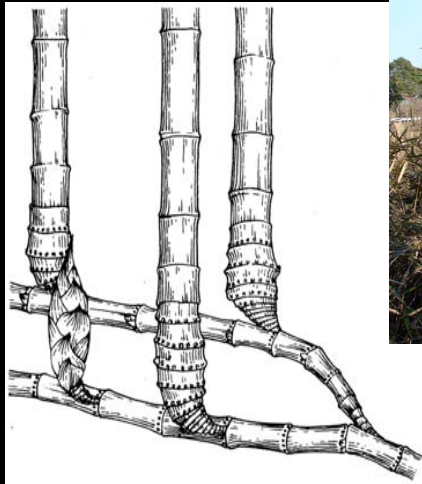
G Reiners

Temperate woody bamboos:

28 genera, 533 species



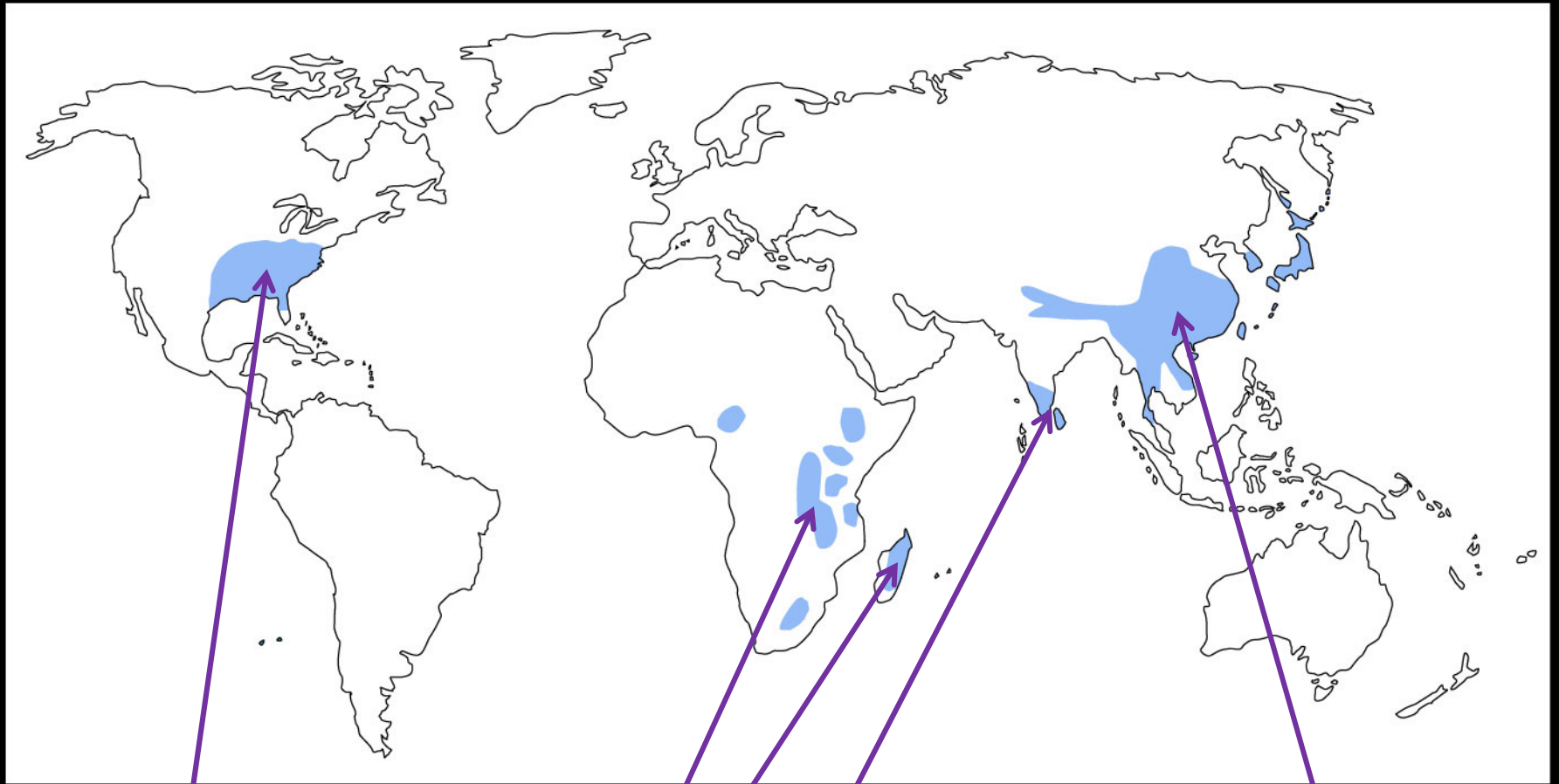
De-Zhu Li,
Chris Stapleton



Major defining characters:

- Leptomorph, monopodial rhizomes (but pachymorph in some)
- Tetraploidy ($2n=48$)
- Basipetal vegetative branch development
- Molecular evidence

Temperate woody bamboos



E North America

3 species

Afro-Indian montane

~20 species

E Asia

~510 species

Diversity within Arundinarieae



J Triplett

Chimonocalamus



J Triplett

Pleioblastus



Indosasa



Phyllostachys



Arundinaria



L Attigala

A. densifolia



Fargesia



J Triplett

Sarocalamus

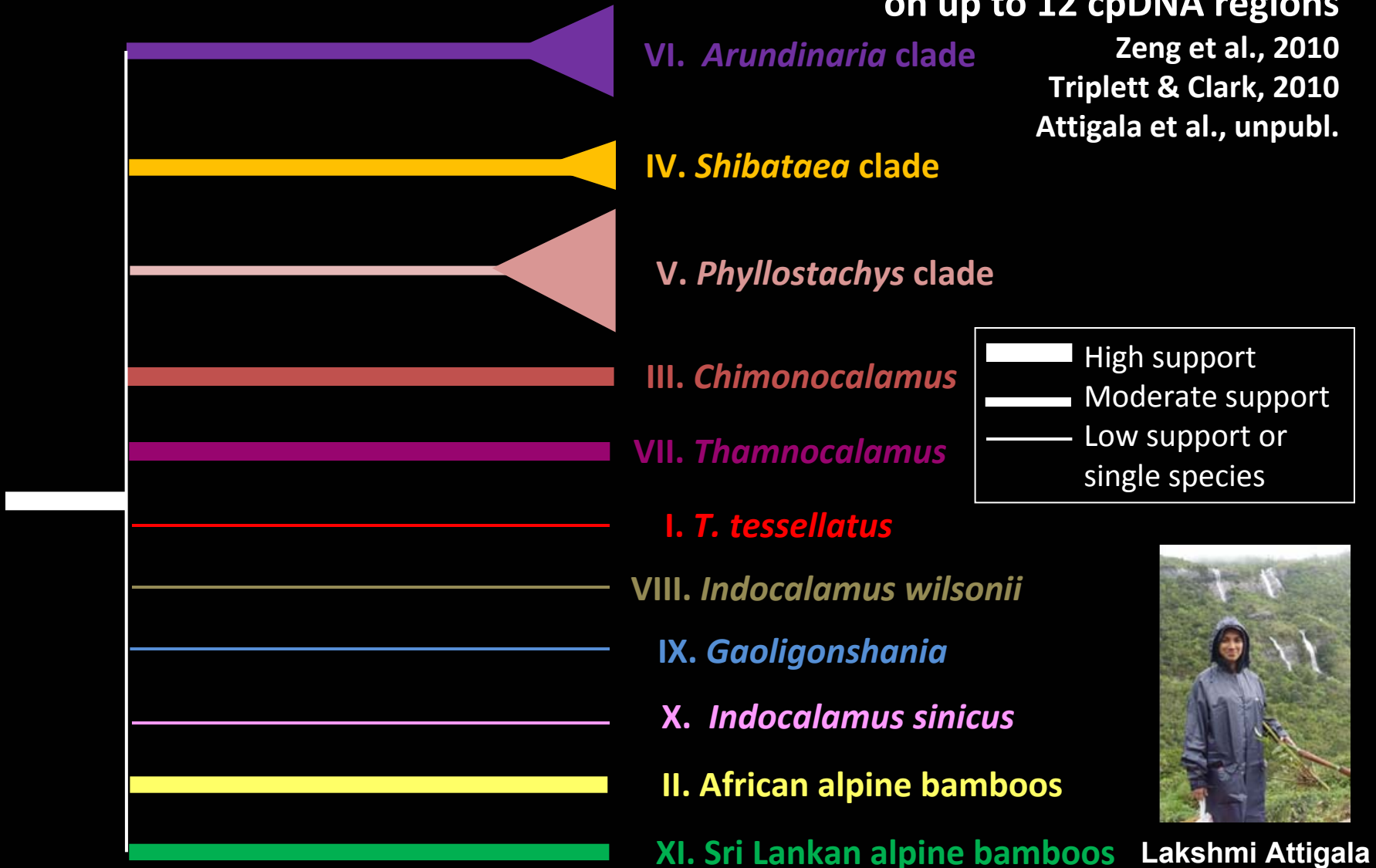
Major lineages of the temperate clade

Summary phylogenetic tree based
on up to 12 cpDNA regions

Zeng et al., 2010

Triplett & Clark, 2010

Attigala et al., unpubl.



Lakshmi Attigala

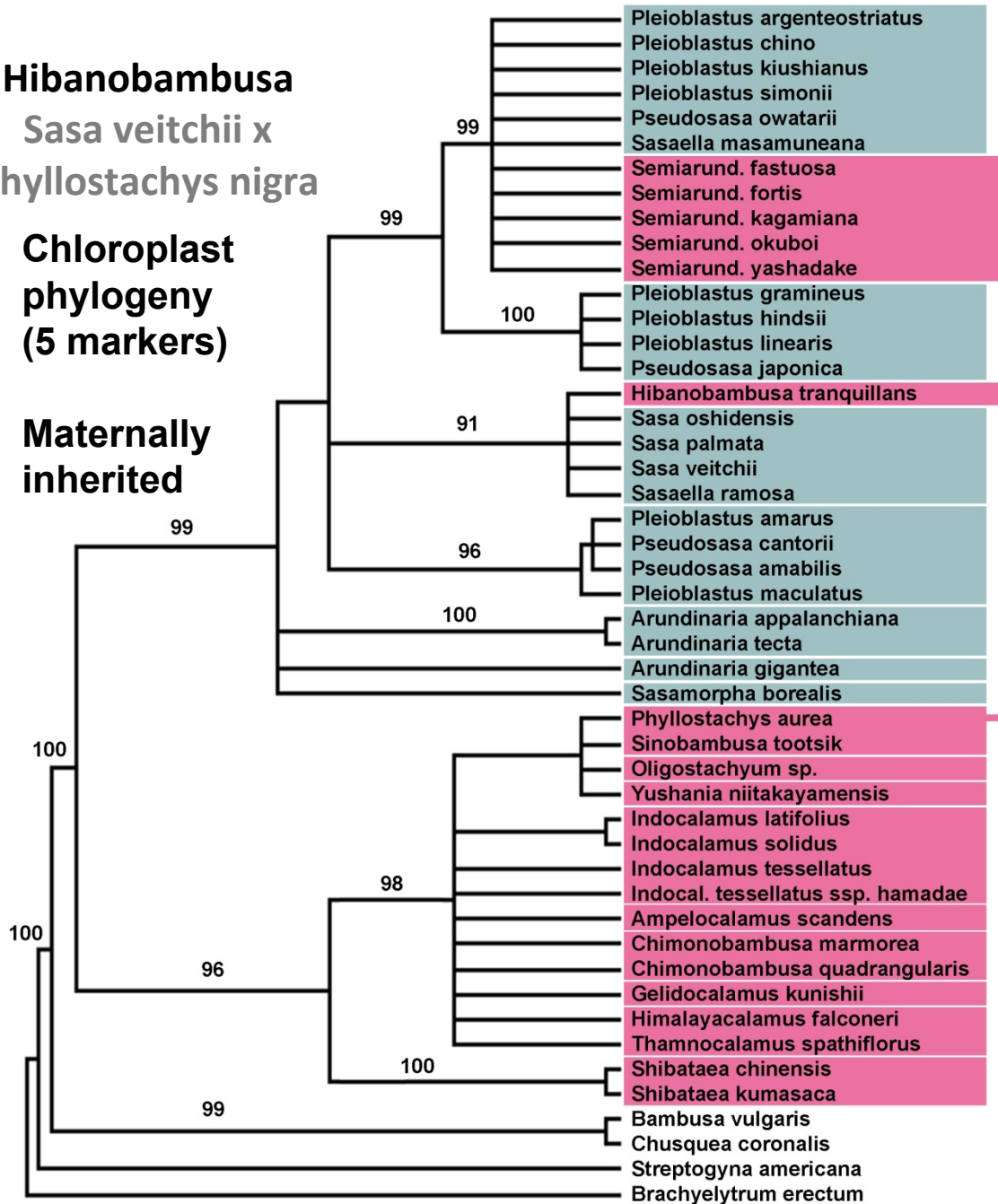
Hibanobambusa

Sasa veitchii x

Phyllostachys nigra

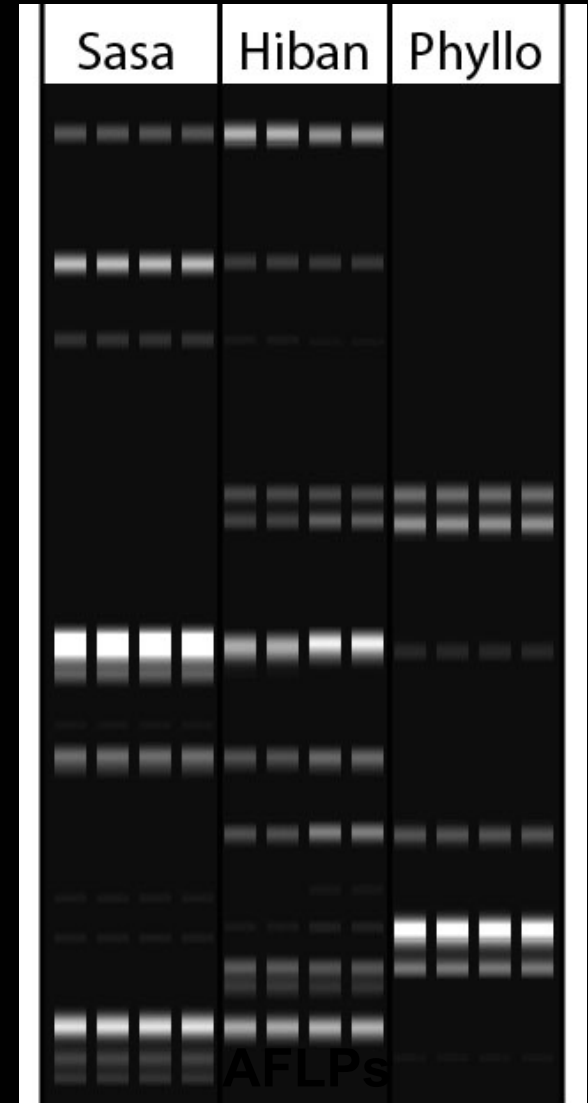
Chloroplast
phylogeny
(5 markers)

Maternally
inherited



Data from J. Triplett

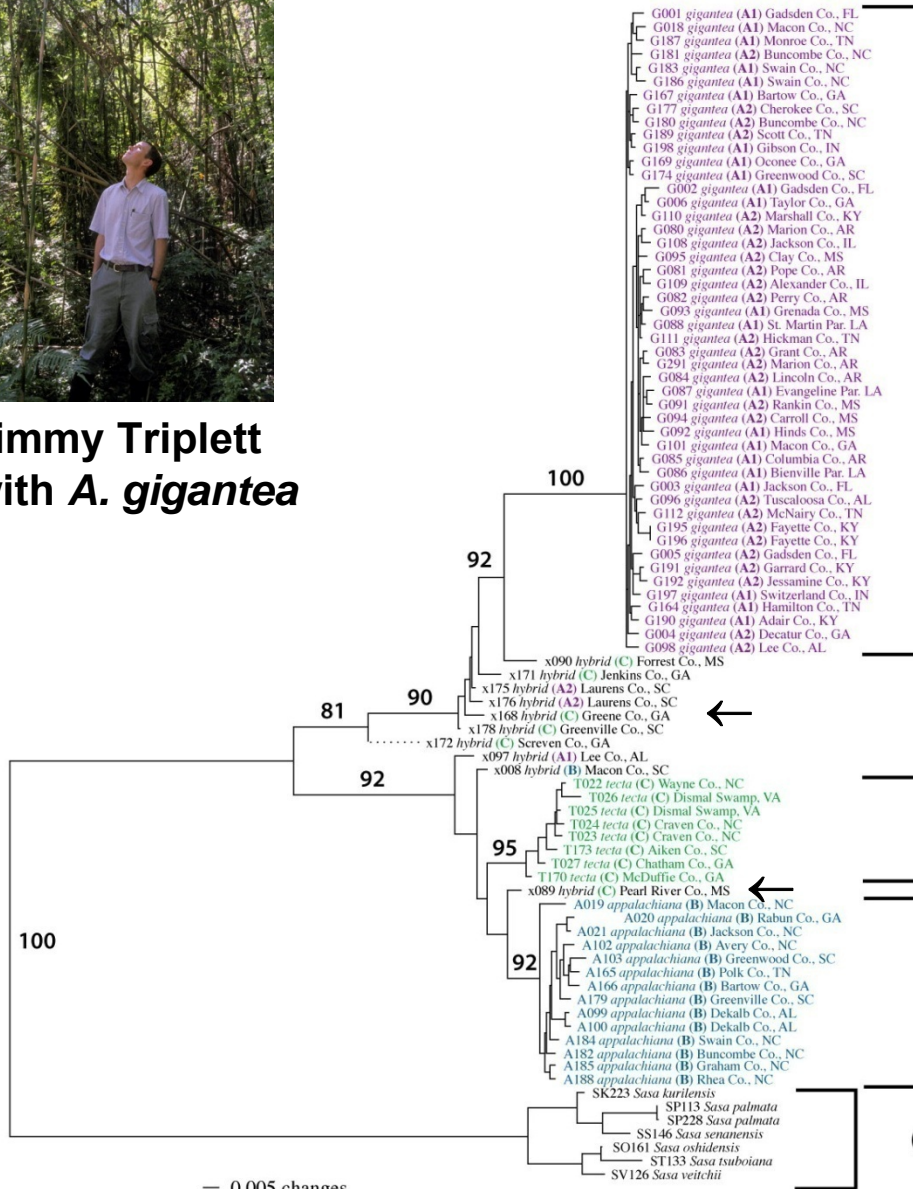
AFLPs—**from both parents**





Jimmy Triplett
with *A. gigantea*

Arundinaria AFLP analysis 4 primer pairs (data from J. Triplett)

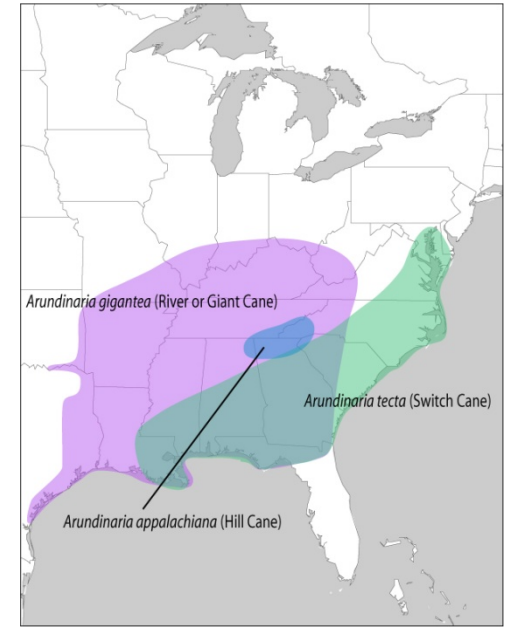


A. gigantea
(River cane)

A. tecta
(Switch cane)

A. appalachiana
(Hill cane)

Outgroup (*Sasa*)



Natural
hybridization
also occurs!

— 0.005 changes

Bambuseae (tropical woody bamboos)

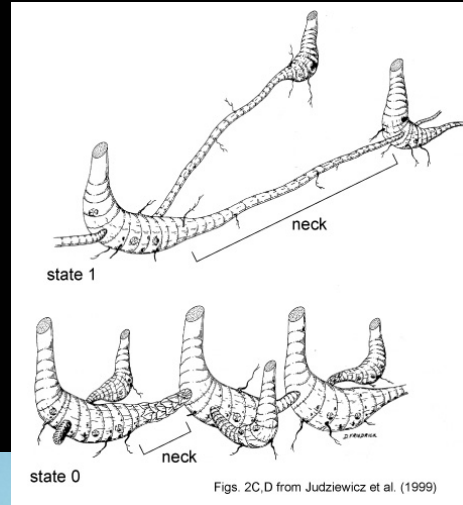


Tropical woody bamboos:

66 genera, 784 species



Ximena Londoño,
Emmet Judziewicz



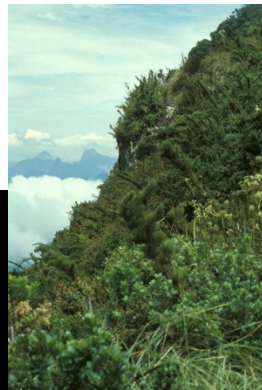
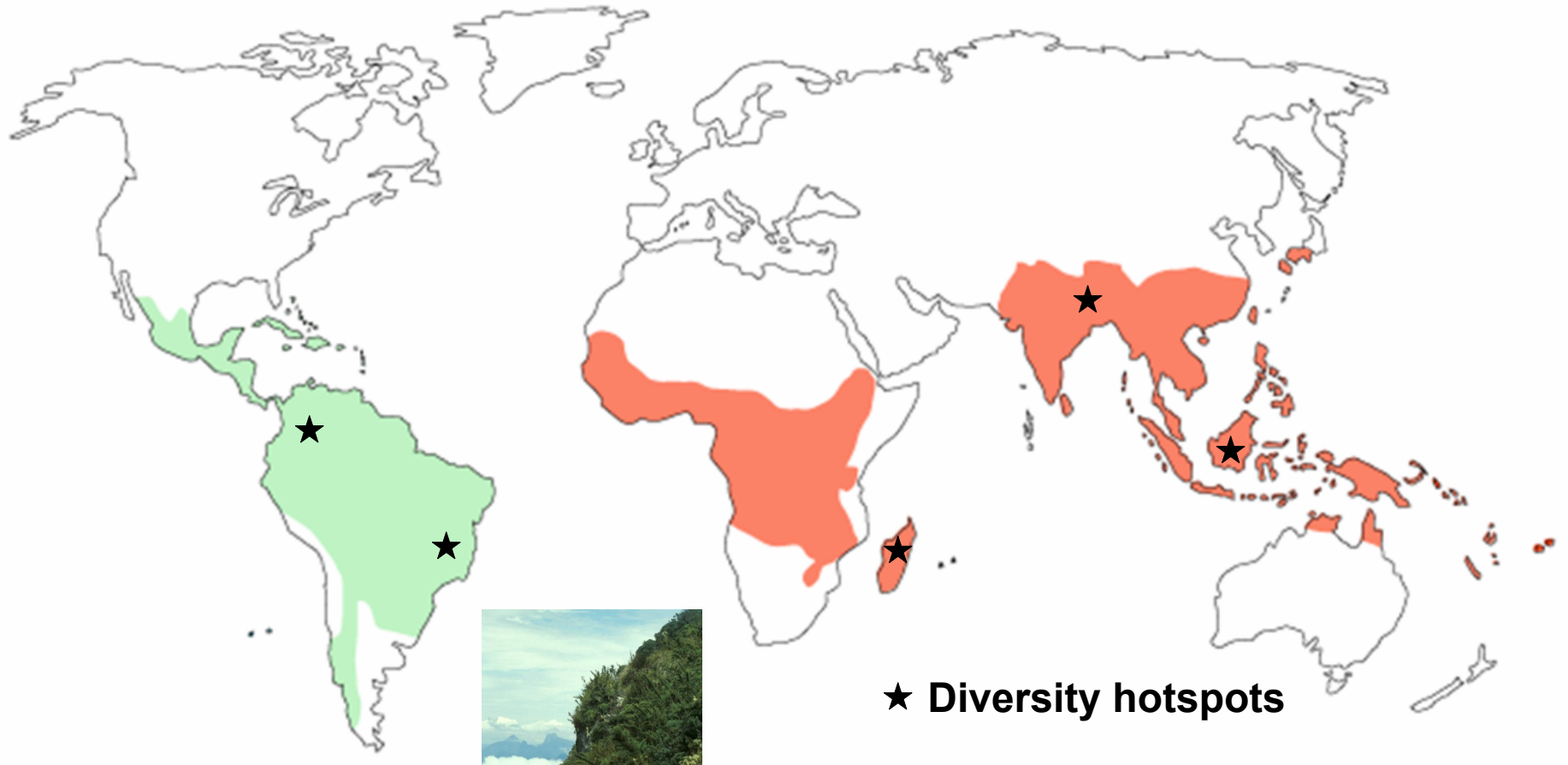
Figs. 2C,D from Judziewicz et al. (1999)

Major defining characters:

- Pachymorph rhizomes
- Tetraploidy or hexaploidy
- Acropetal or bidirectional vegetative branch development
- Molecular evidence

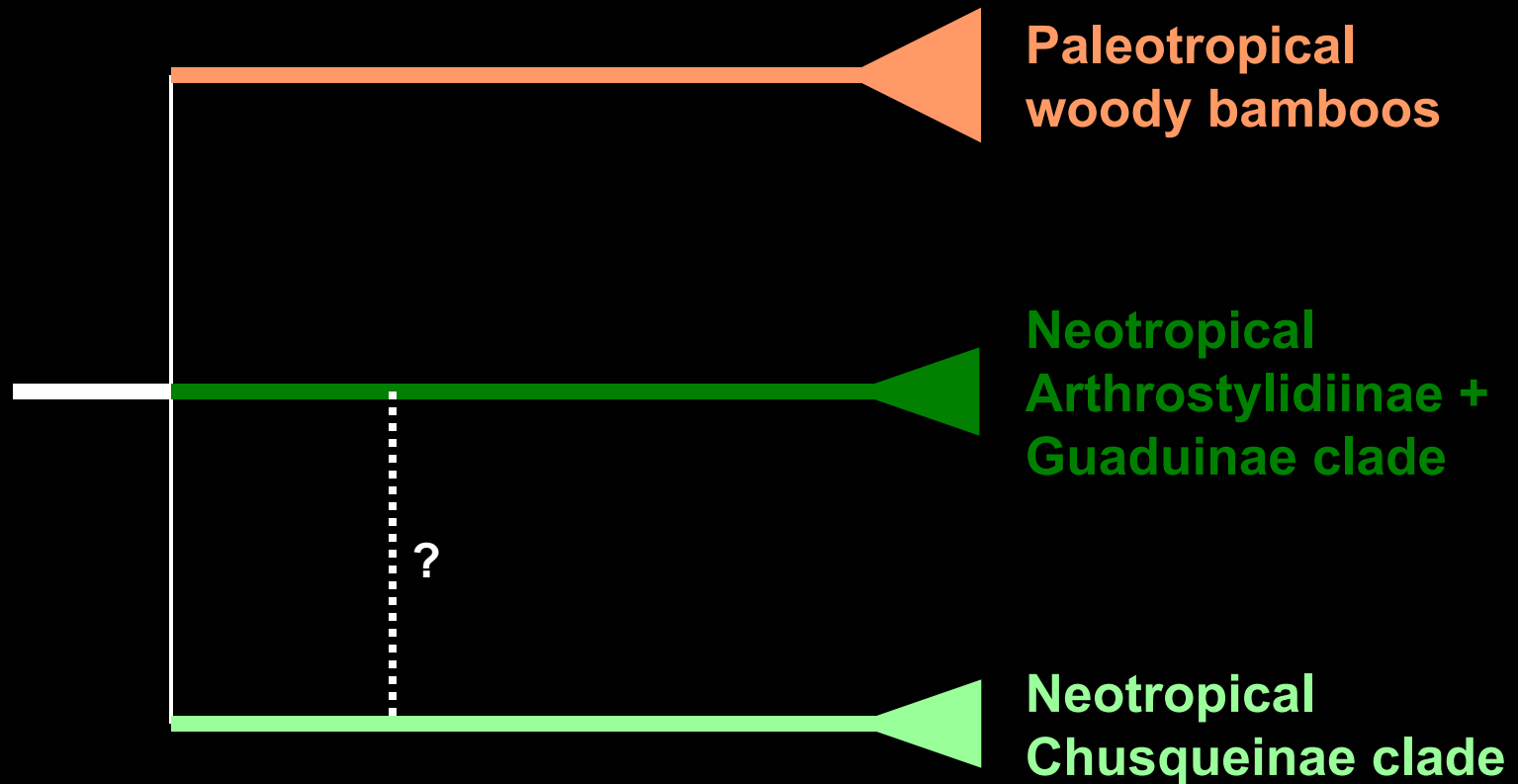


Bambuseae distribution

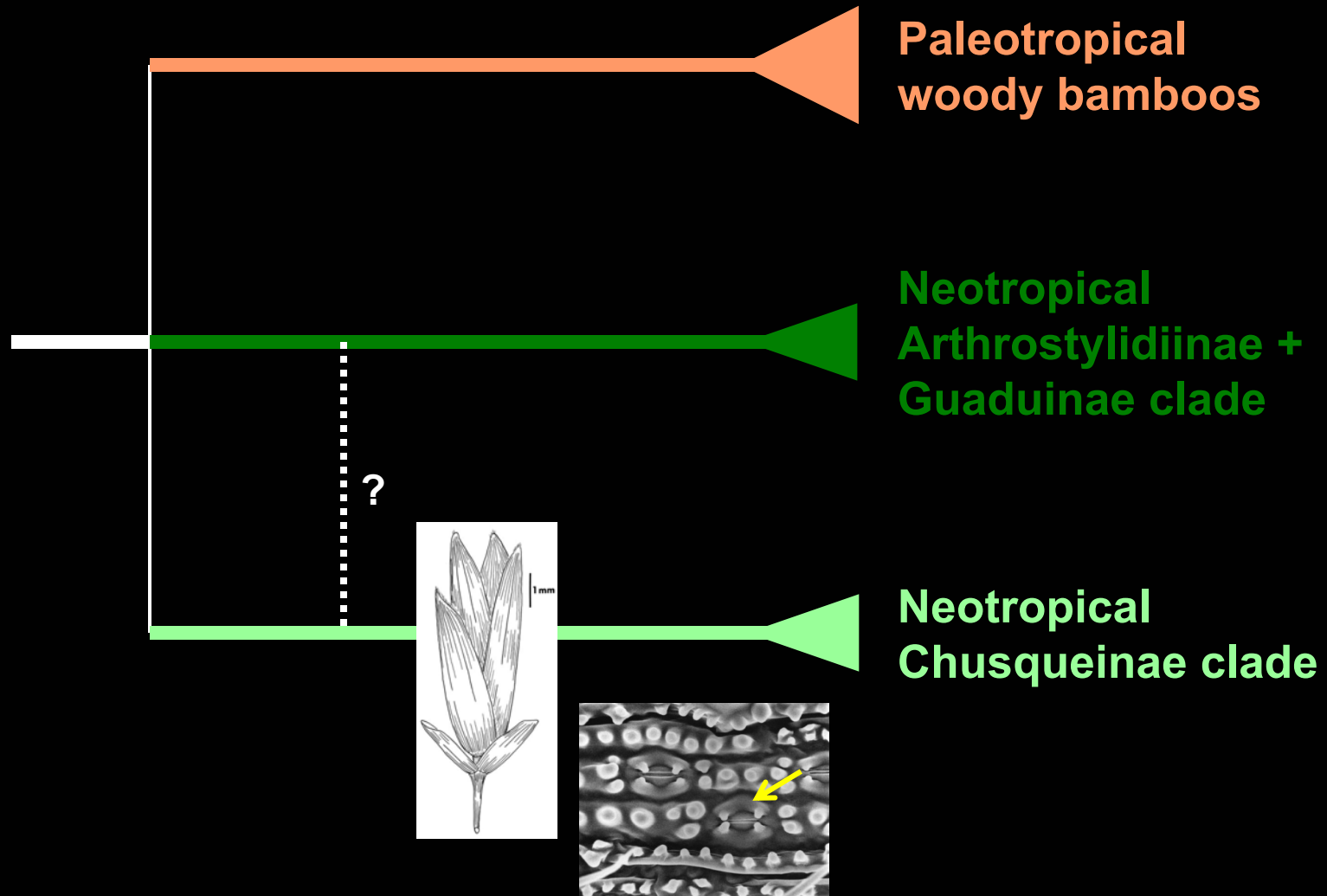


Woody bamboo diversity is strongly associated with mountains

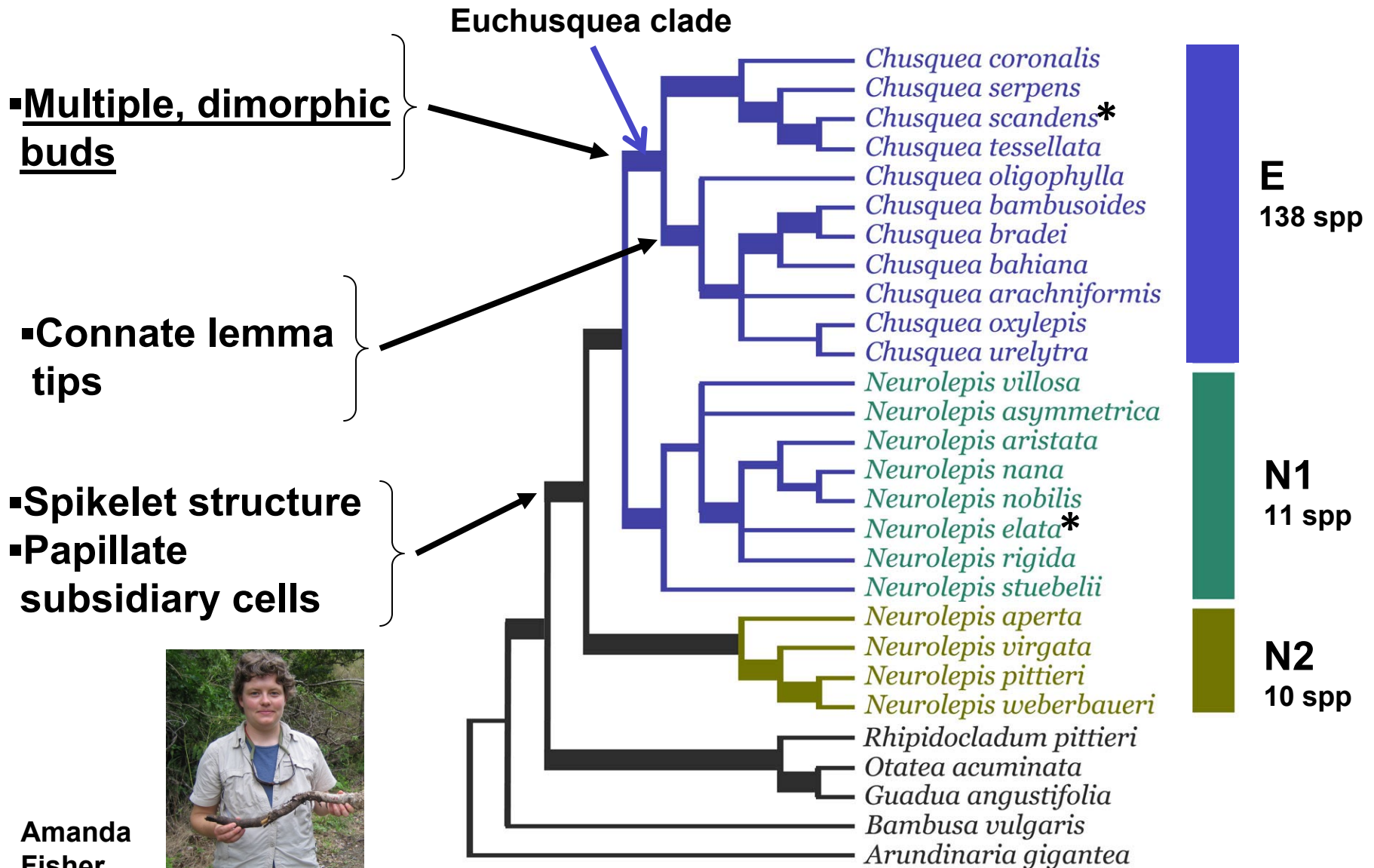
Major lineages of the tropical woody bamboos



Major lineages of the tropical woody bamboos



Evolutionary relationships within Chusqueinae



Amanda Fisher



Key innovation in Chusqueinae?



single bud
in most bamboos
giving rise to
complex branching
patterns

single buds but no



branch development
in "*Neurolepis*" (21 spp)



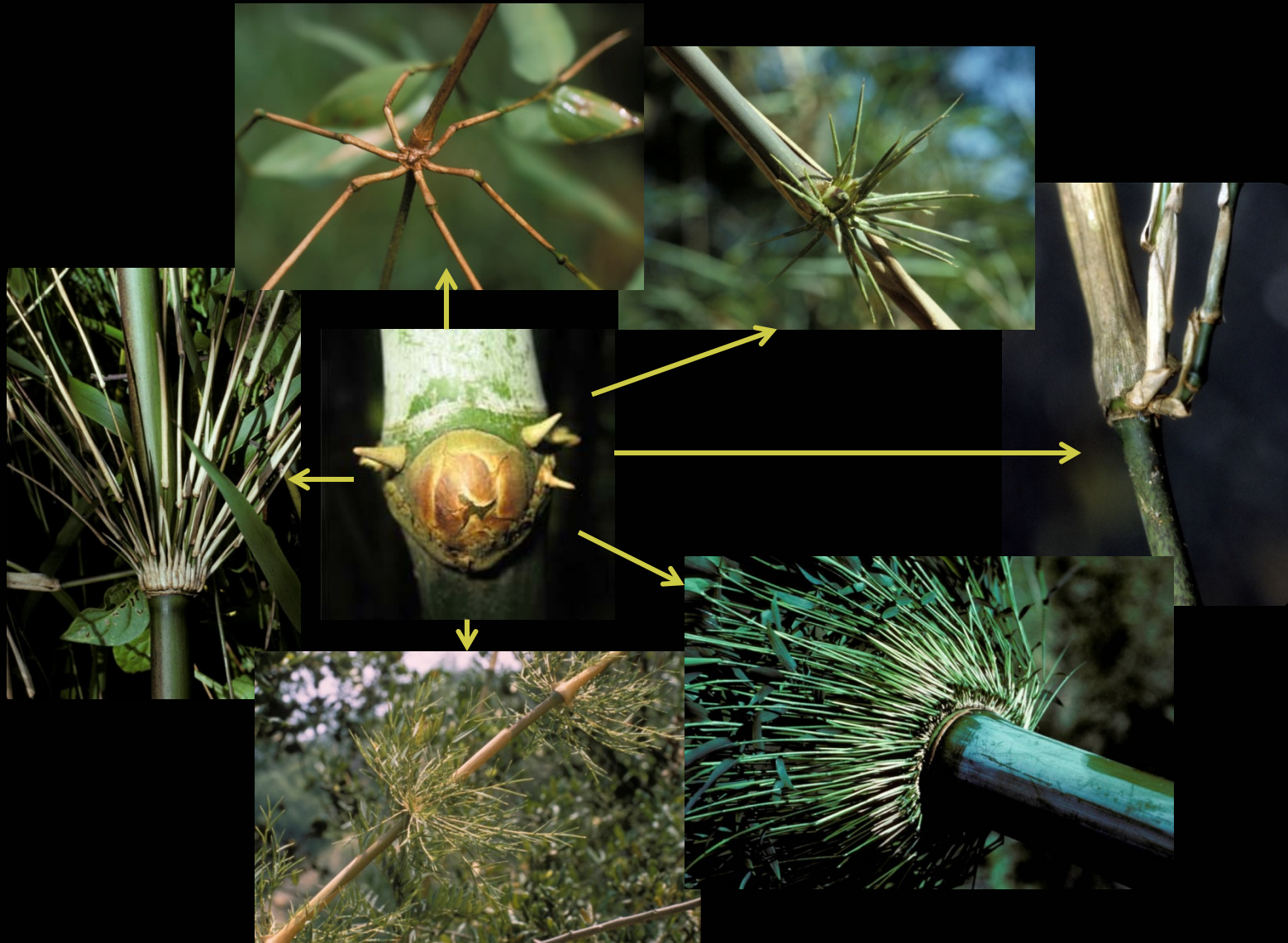
multiple, dimorphic
buds in the
Euchusquea clade
(138 spp)



Toni
Grieb



Branching patterns in *Chusquea* (the *Euchusquea* clade)

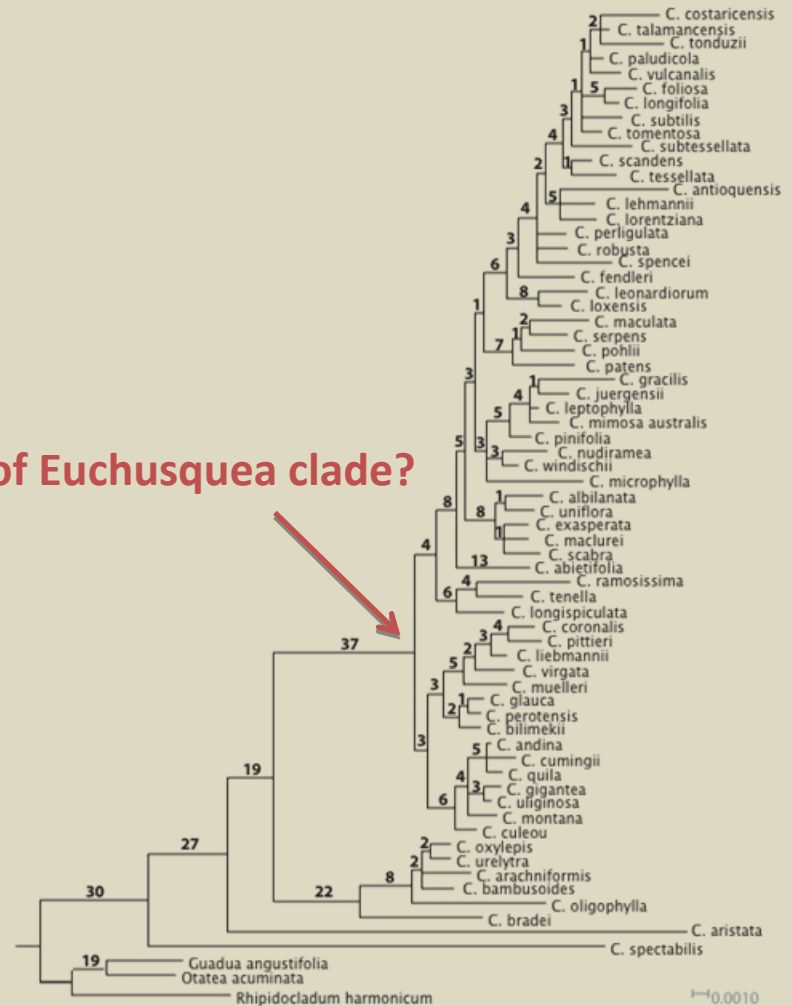


The Euchusquea clade shows high species diversity yet low genetic variation

Low variation (>5K nucleotides, 260 PICs)

Recent origin of Euchusquea clade?

Data from
A. Fisher

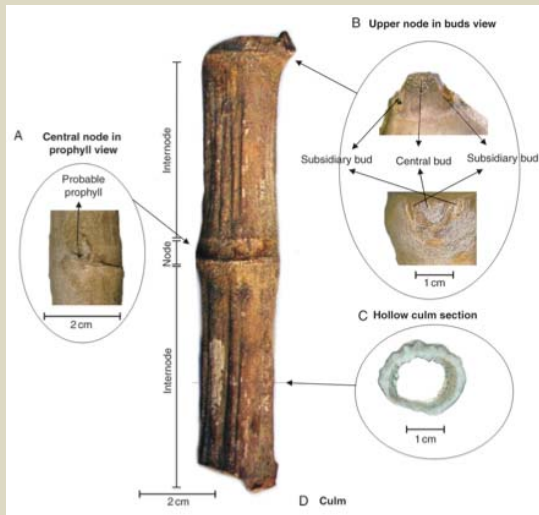


BEAST software

Bayesian framework

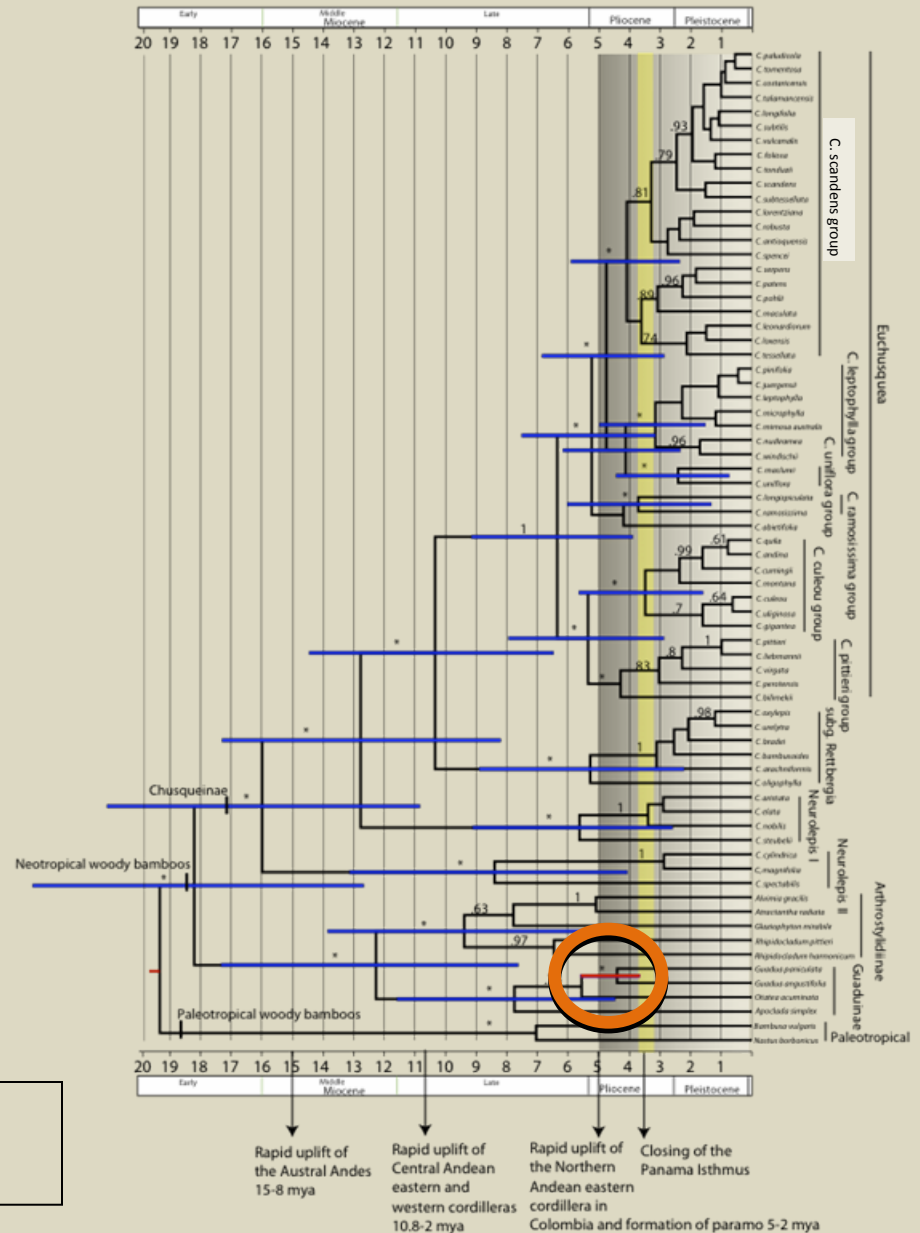
chloroplast sequence data

1. Secondary calibration from a molecular dating analysis of Poaceae
14 – 24.8 mya
(Kelchner & Fisher unpublished)
2. Neotropical woody bamboo fossil
3.6 – 11.8 mya
(Brea & Zucol 2007)



Data from A. Fisher

Molecular dating analysis of *Chusquea*



Molecular dating analysis of *Chusquea*

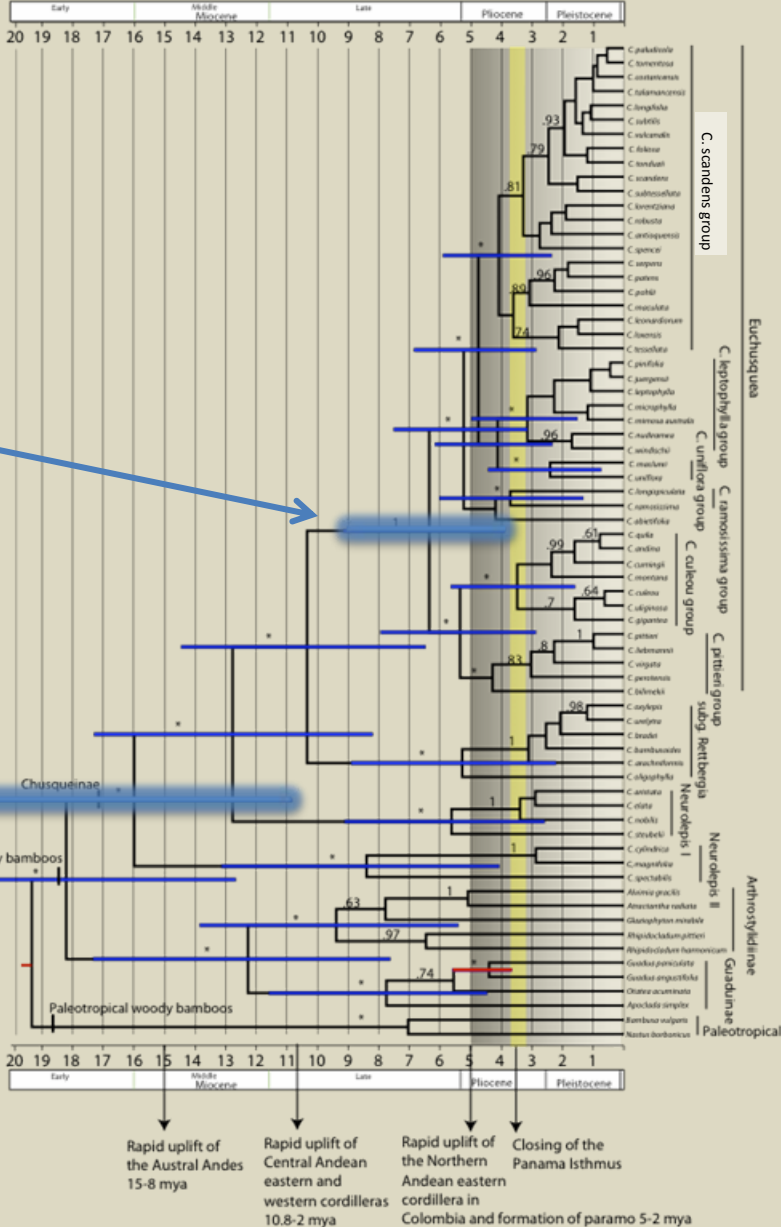


Estimated divergence of the *Euchusquea* clade in the late Miocene to Pliocene (3.9-9.16 mya)

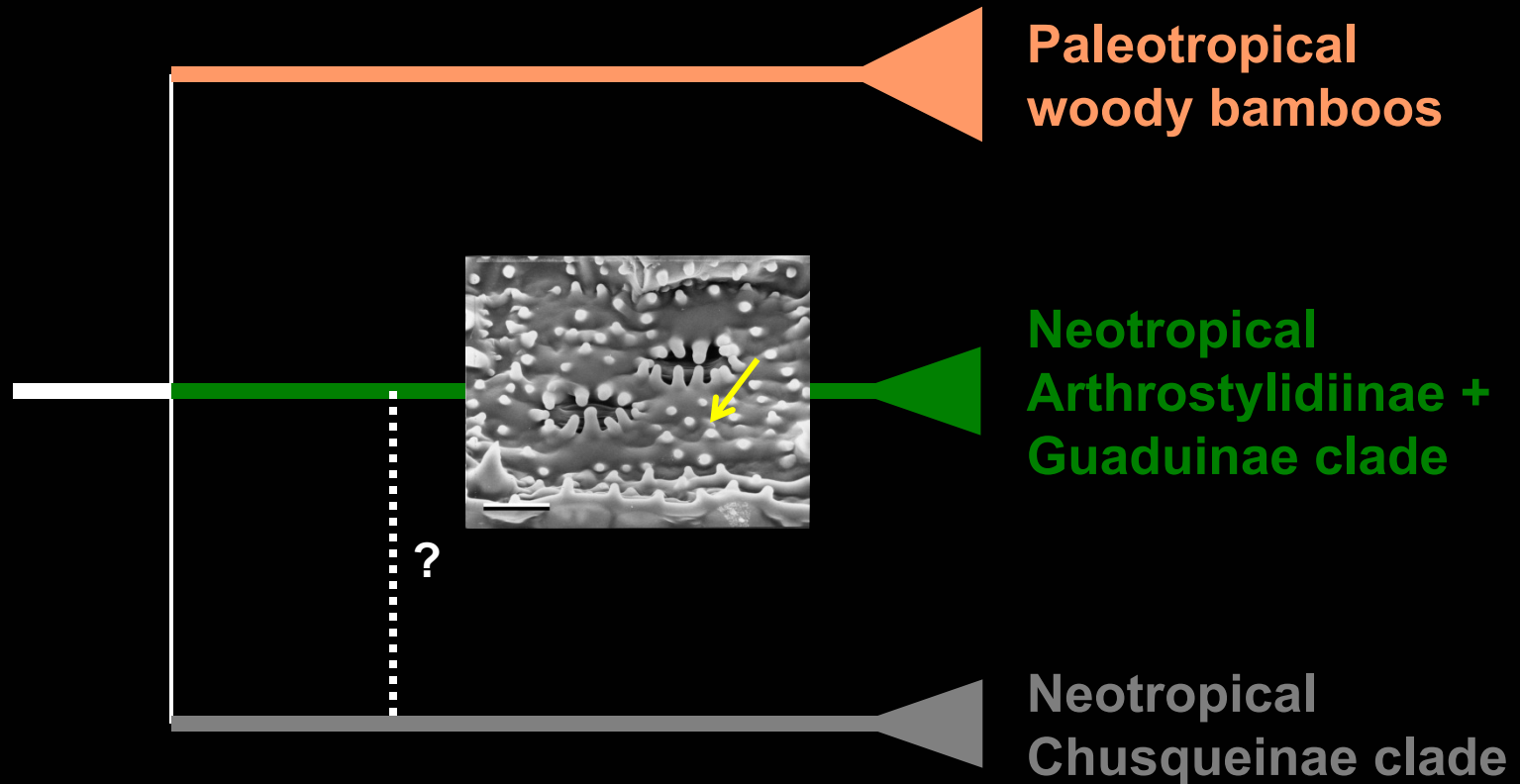
Estimated divergence of *Chusquea* In the Miocene (10.8-21 mya)



Data from A. Fisher



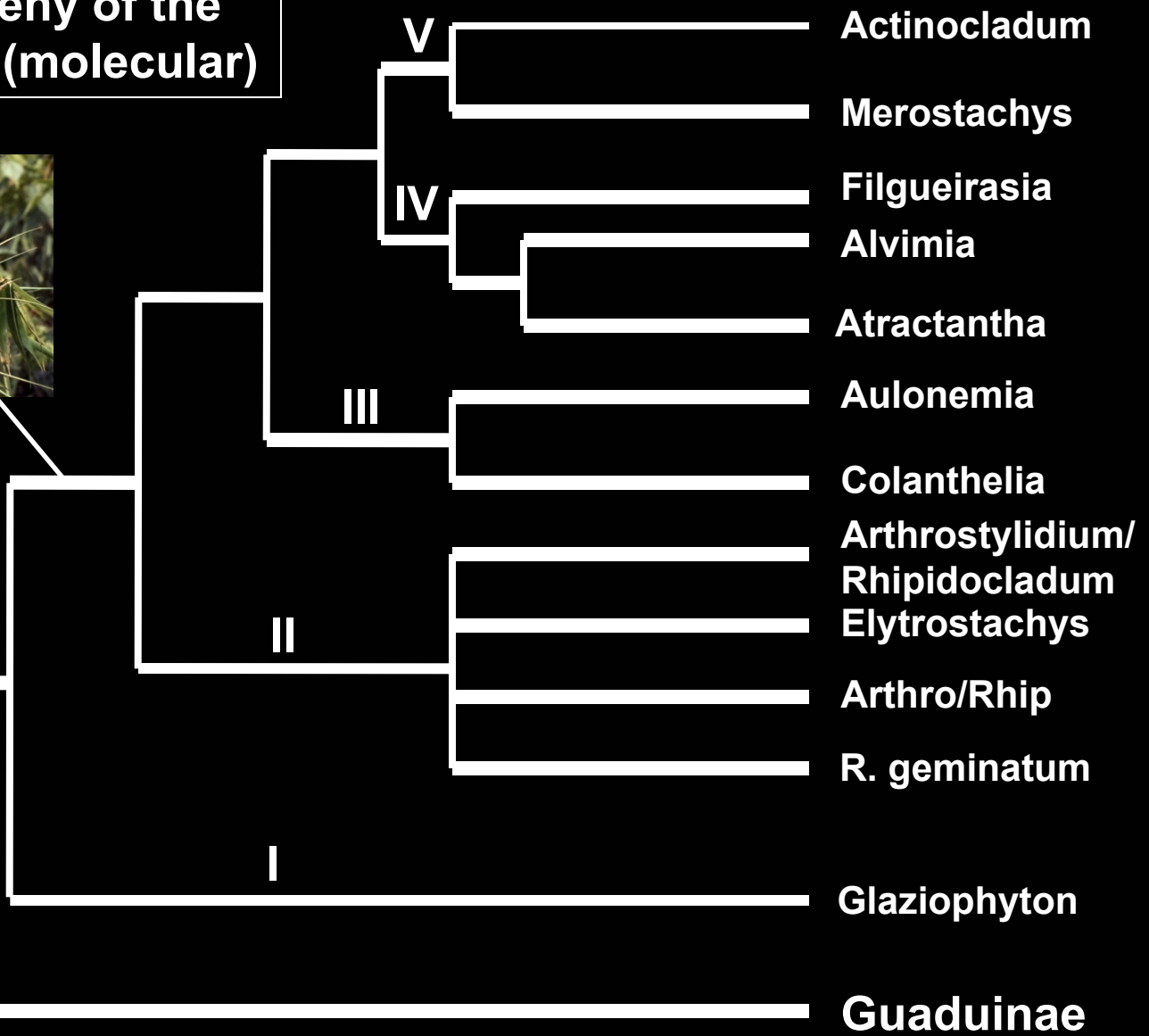
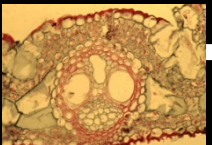
Major lineages of the tropical woody bamboos



Summary phylogeny of the Arthrostylidiinae (molecular)



Leaf anatomy/ morphology



Actinocladum

Merostachys

Filgueirasia

Alvimia

Atractantha

Aulonemia

Colantheia

**Arthrostylidium/
Rhipidocladum**

Elytrostachys

Arthro/Rhip

R. geminatum

Glaziophyton

Guaduinae

**What did the ancestor of
Arthrostylidiinae look like
and where in South America
did the subtribe originate?**

Glaziophyton



**Tom
Soderstrom**

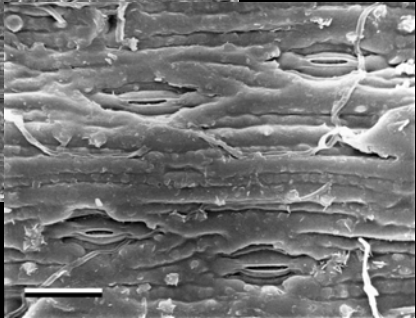
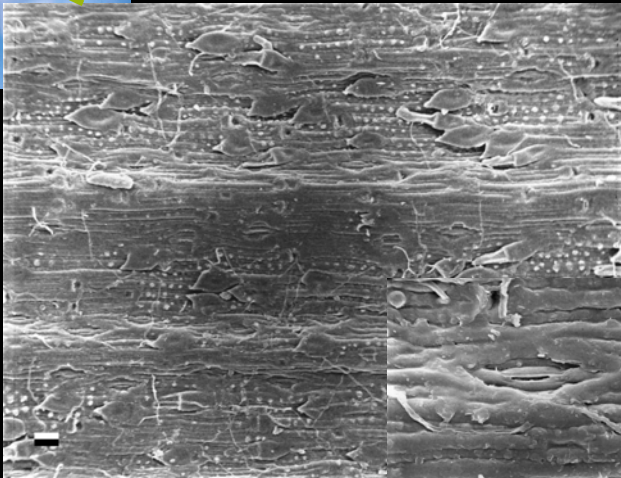
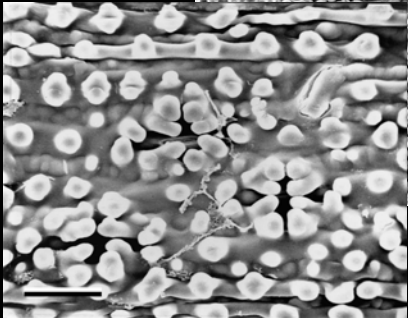
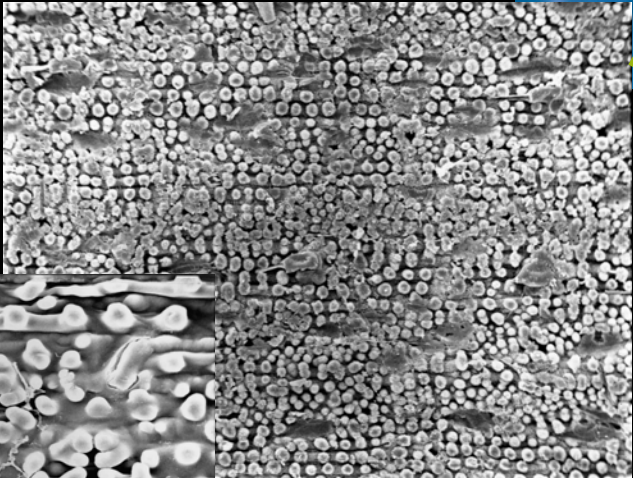
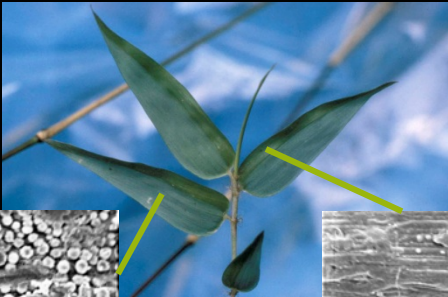
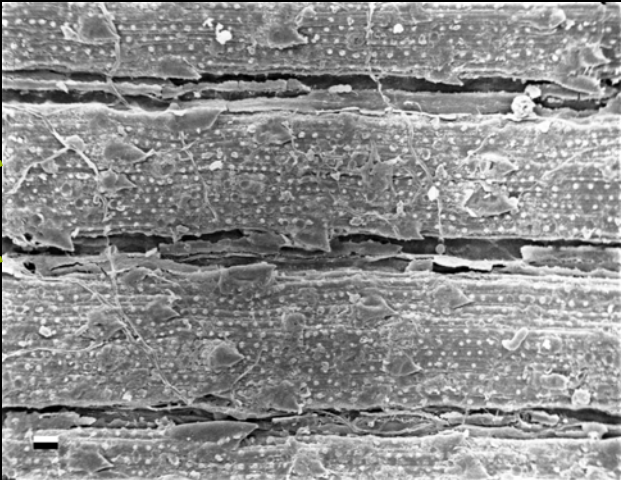


Other Arthrostylidiinae

Leaf anatomy and micromorphology in Arthrostylidiinae

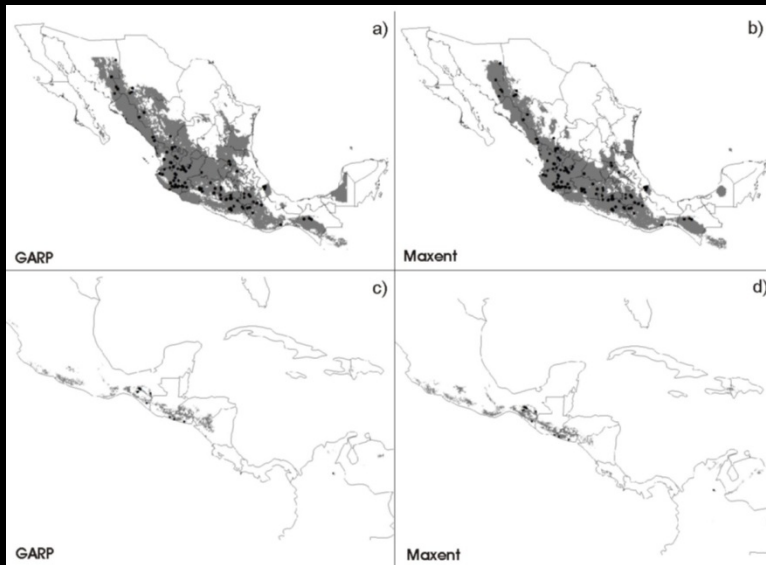


Ana Paula Santos-Gonçalves



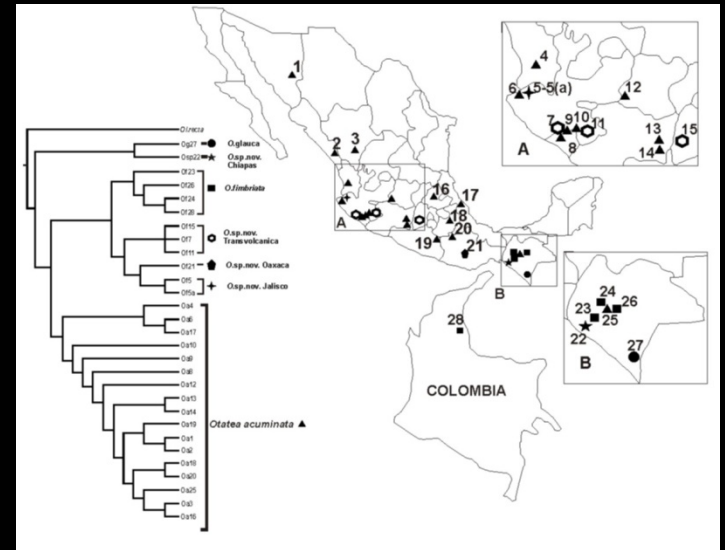
Describing bamboo diversity

1999: 3 species of *Otatea* (Guaduinae)
(Judziewicz et al. 1999)



Ecological niche modeling

+



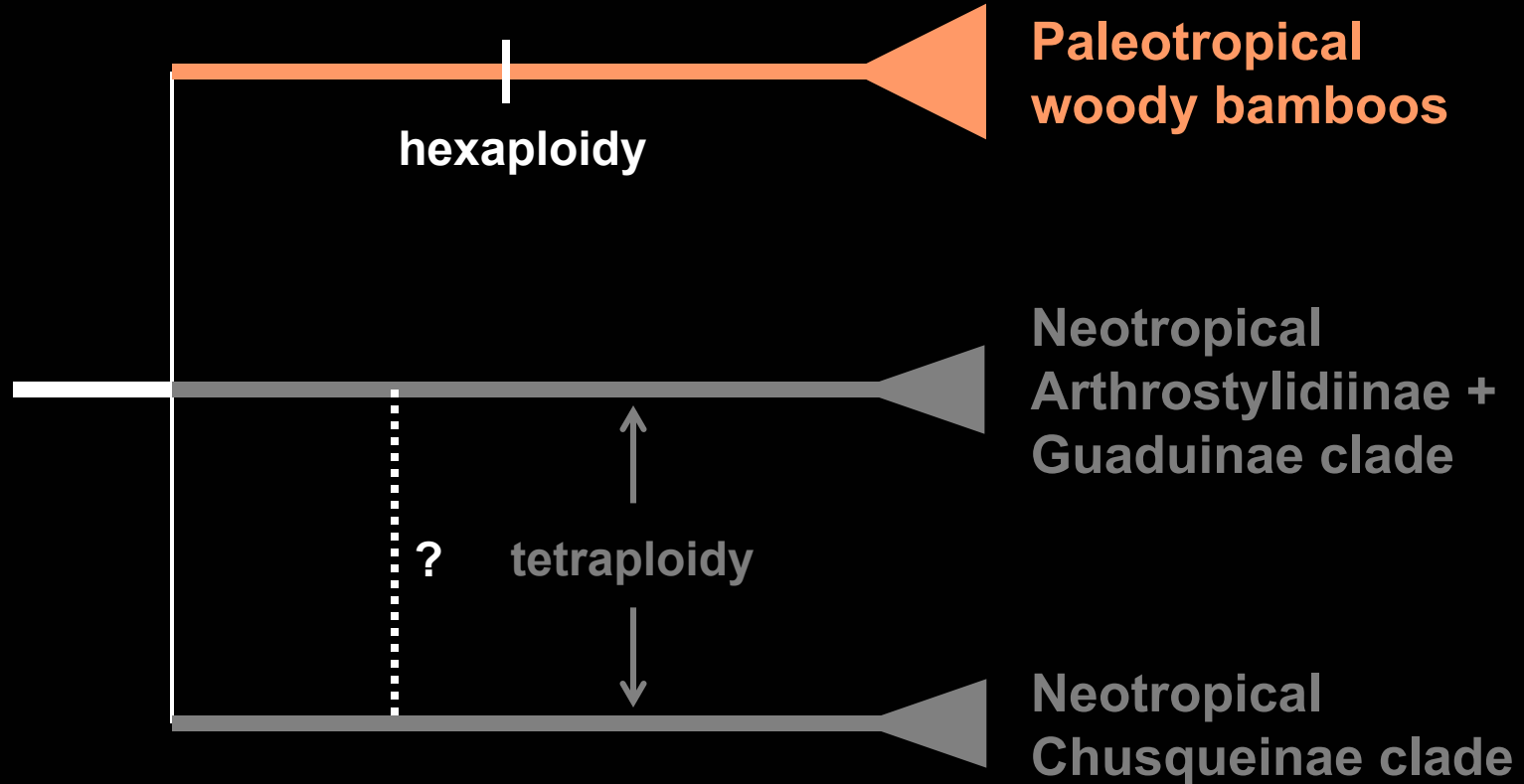
Population genetic analysis



2011: 8 species of *Otatea* (Guaduinae)
(Ruiz & Sosa 2010; Ruiz et al. 2011; Ruiz, in press)



Major lineages of the tropical woody bamboos



Paleotropical woody bamboos

Racemobambosinae



Hickeliinae



S Dransfield



Jatmi Dransfield



T Rodd

4 subtribes,
47 genera,
407 species



Melocanninae



NE India Pics

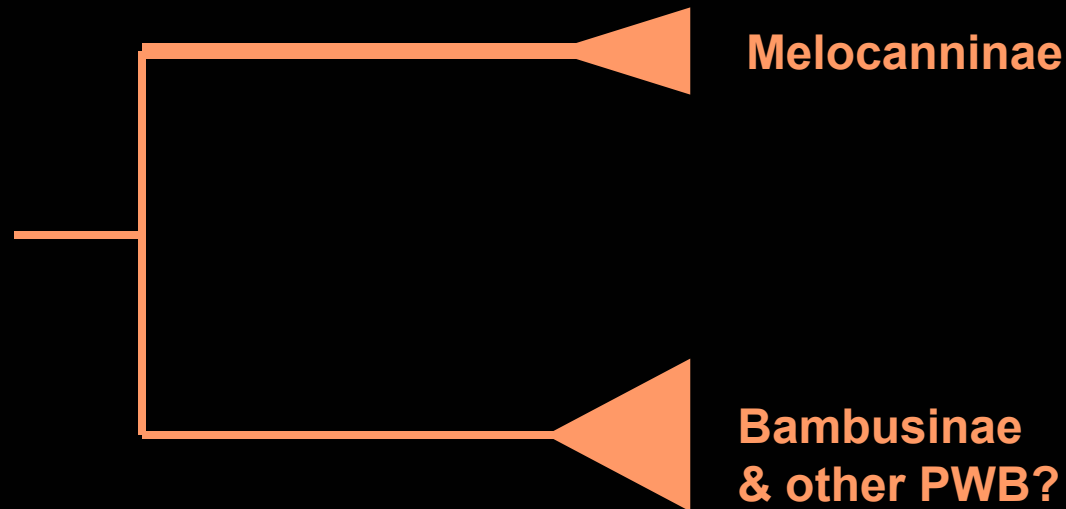


KM Wong

Bambusinae



Relationships within paleotropical woody bamboos



Analyses with broader sampling are ongoing (by Chokthaweepanich et al.)...but natural hybridization is documented within Bambusinae (Goh et al., in press).

Summary of most significant recent advances in bamboo evolution



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- **Estimated origin of the bamboos ca. 30 mya; 3 major lineages (herbaceous, temperate woody and tropical woody)**



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- Hybridization (both between and within genera) common in each tribe
- Vegetative characters extremely important in understanding bamboo evolution

Summary of most important changes in bamboo classification



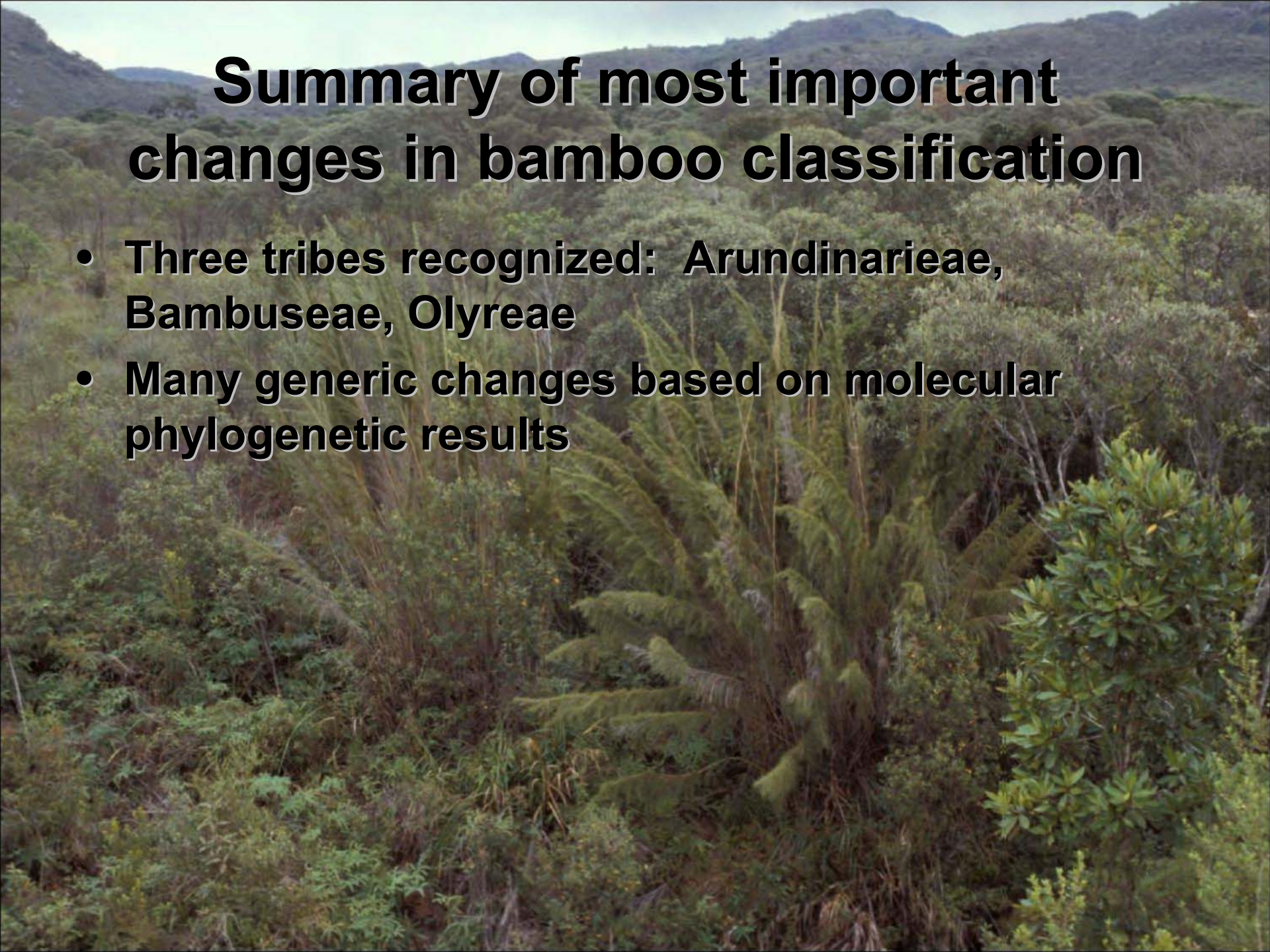
Summary of most important changes in bamboo classification

- Three tribes recognized: Arundinarieae, Bambuseae, Olyreae



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- Many generic changes based on molecular phylogenetic results



Summary of most important changes in bamboo classification

- Three tribes recognized: Arundinarieae, Bambuseae, Olyreae
- Many generic changes based on molecular phylogenetic results
- Numbered lineages used in temperate bamboos; traditional subtribes discarded because they don't reflect known relationships

Summary of most important changes in bamboo classification

- Three tribes recognized: Arundinarieae, Bambuseae, Olyreae
- Many generic changes based on molecular phylogenetic results
- Numbered lineages used in temperate bamboos; traditional subtribes discarded because they don't reflect known relationships
- 7 subtribes in tropical woody bamboos continue to be recognized as these do reflect evolutionary relationships

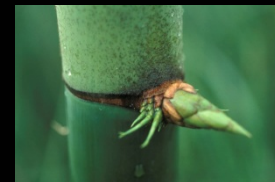
A photograph of a dense, green, and brownish scrubland or grassy area. The vegetation consists of various types of grasses and small plants, some with long, narrow leaves and others with more rounded, bushy forms. The colors range from vibrant green to a brownish-green, suggesting some dryness or a specific environmental condition. The text "Current directions" is overlaid in the center of the image in a bold, black, sans-serif font.

Current directions

I. Resolving relationships

Woody habit
& culm leaves
Complex branching
Gregarious
monocarpy

Tropical
woody bamboos



Olyreae

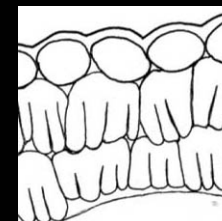


(loss)

Temperate
woody bamboos



+



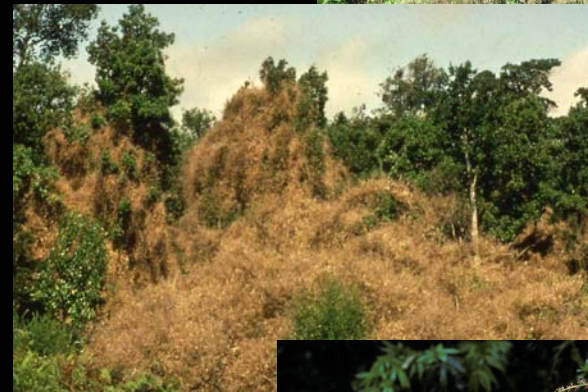
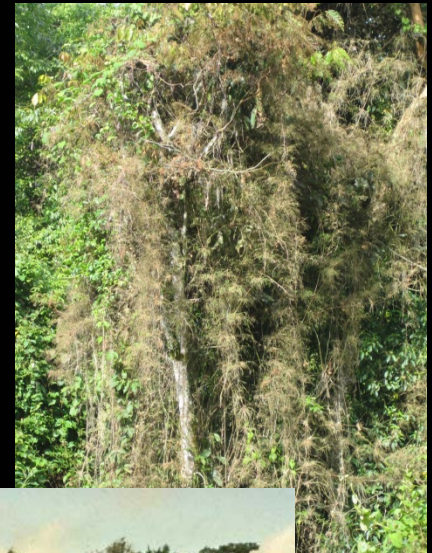
II. Flowering behavior in woody bamboos

Cycles vary from a few years to several decades to as much as 120 years.

How do the plants count?

What are the genetic mechanisms controlling flowering?

What selective pressures led to the evolution of gregarious monocarpy in bamboos?



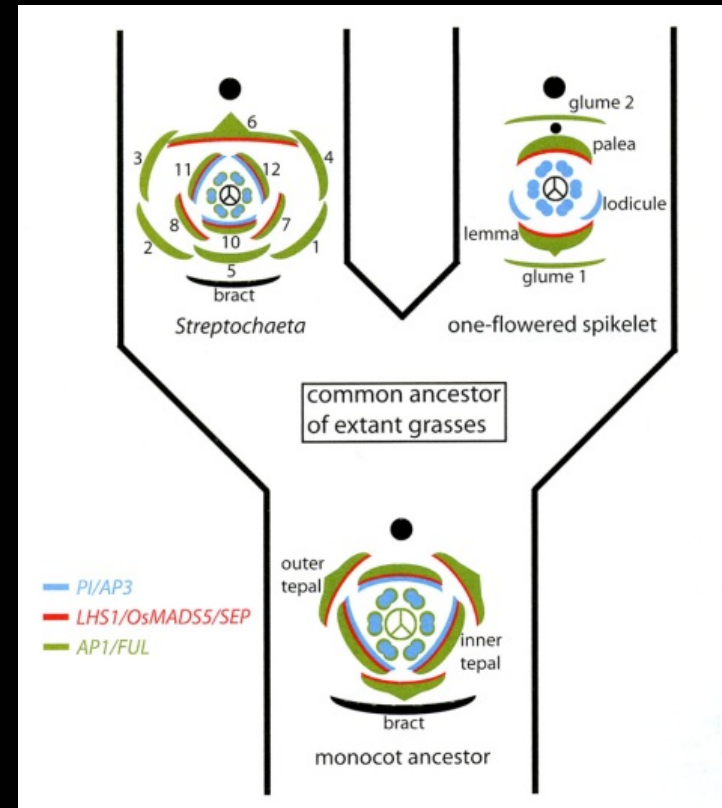
III. Evolution of development



Genes related to rhizome bud development in bamboos
(Wang et al. 2010)



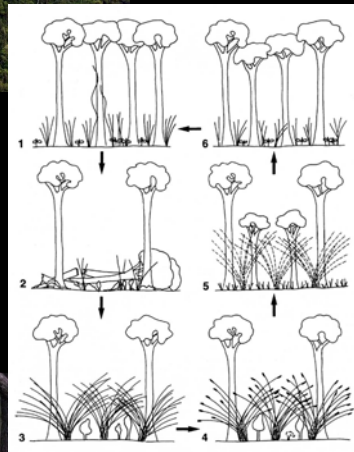
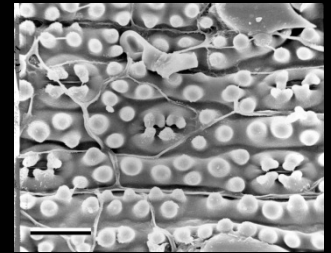
Development of fusoid cells



Genes affecting floral development in grasses
(Preston et al. 2009)

IV. Bamboo ecology

Bamboos & other organisms



Bamboos & forest dynamics, nutrient cycles, erosion control, carbon fixation, rodent outbreaks, etc.



Nat Geo TV

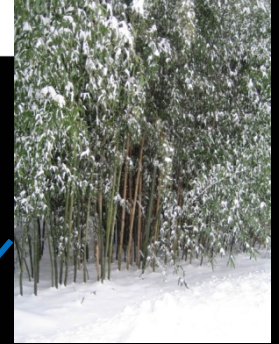
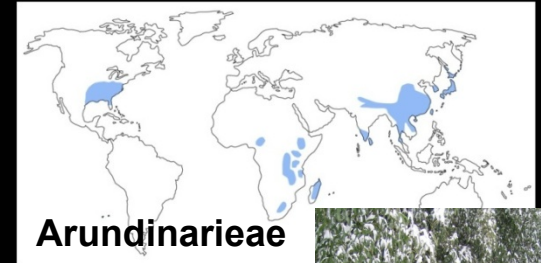
V. Bamboo ecology



Francisca Ely



Tropical bamboos



Bambusoideae

Bambuseae

Olyreae

Arundinarieae

Pooideae
(wheat & allies)

Ehrhartoideae
(rices & allies)



Origin of cold tolerance?

Cold tolerance in the BEP Clade



100s of genes known to affect cold tolerance



Split Responsibly



Funding:
U.S. National Science Foundation
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American Bamboo Society
Iowa State University
9th World Bamboo Congress

Thank You!