Recent advances in phylogenomics of some Neotropical woody plant families

Jérôme Chave

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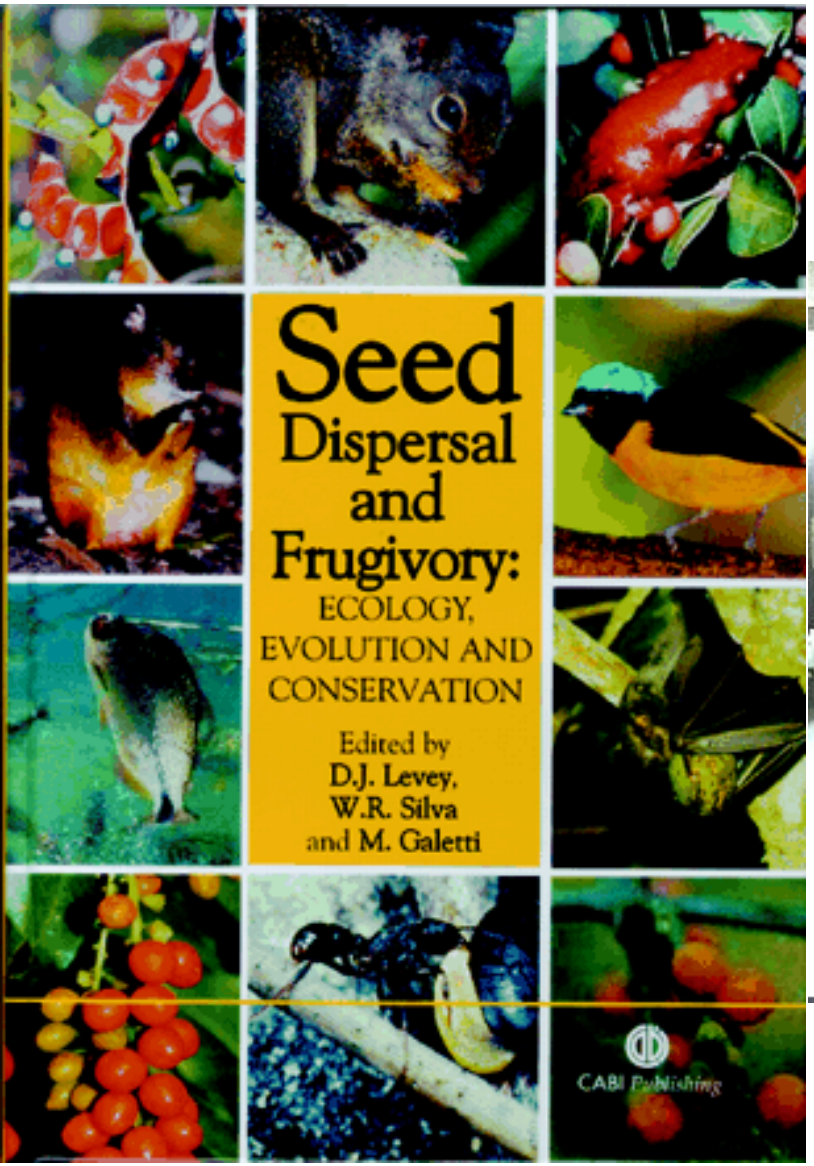
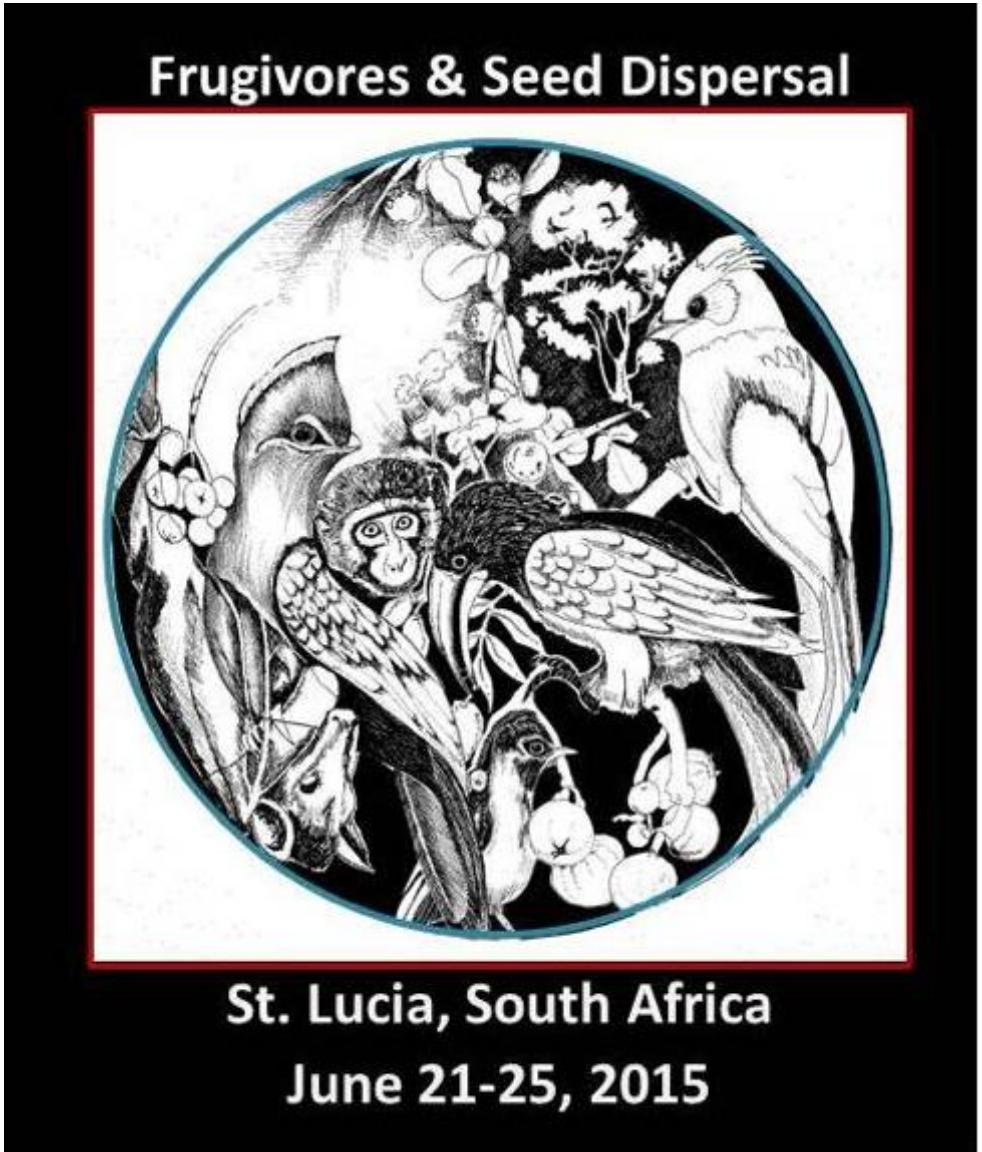
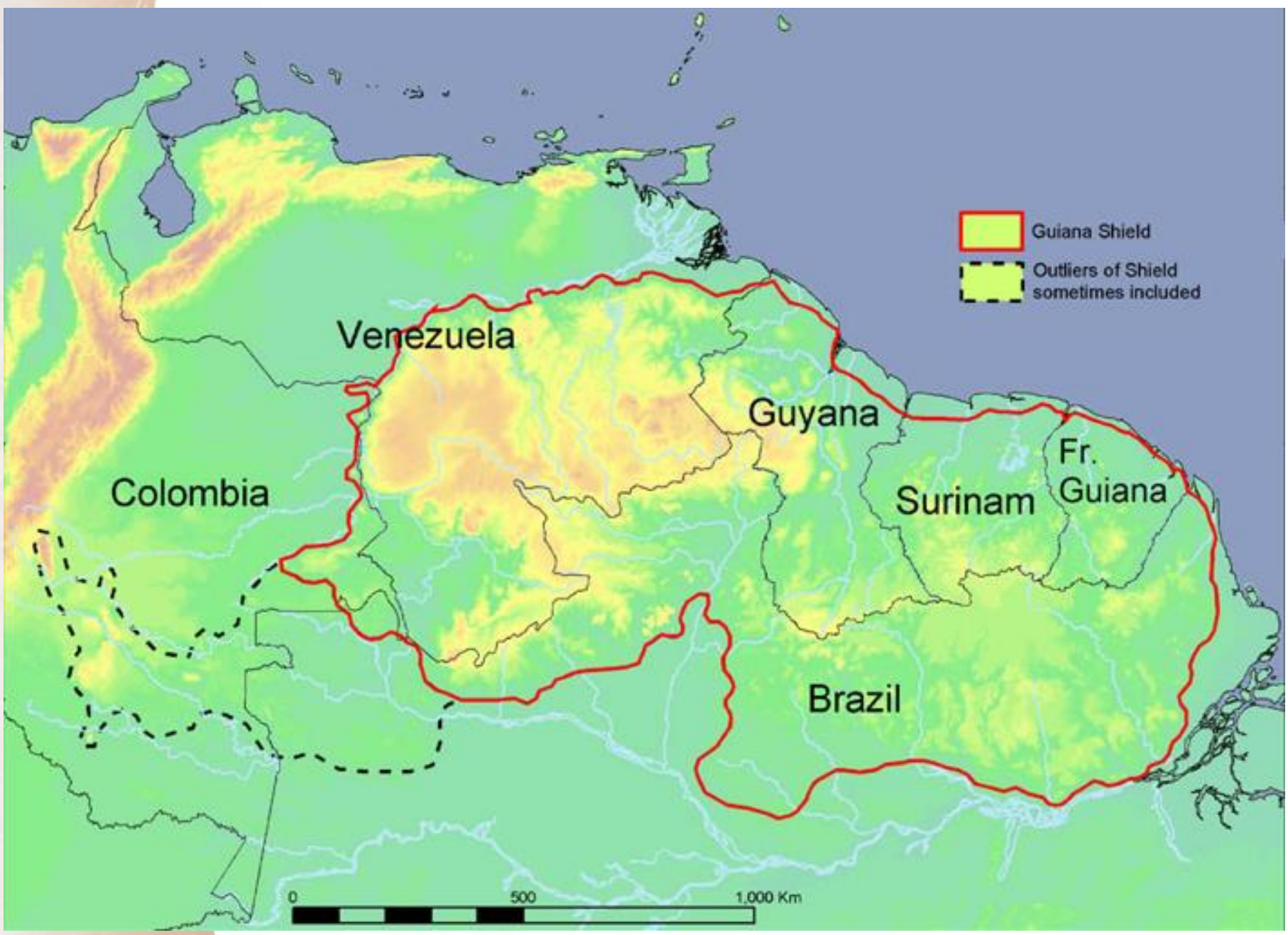


3rd International Symposium-Workshop on Frugivores and Seed Dispersal,
August 6-11, 2000 Hotel Fazenda Fonte Colina Verde in São Pedro.

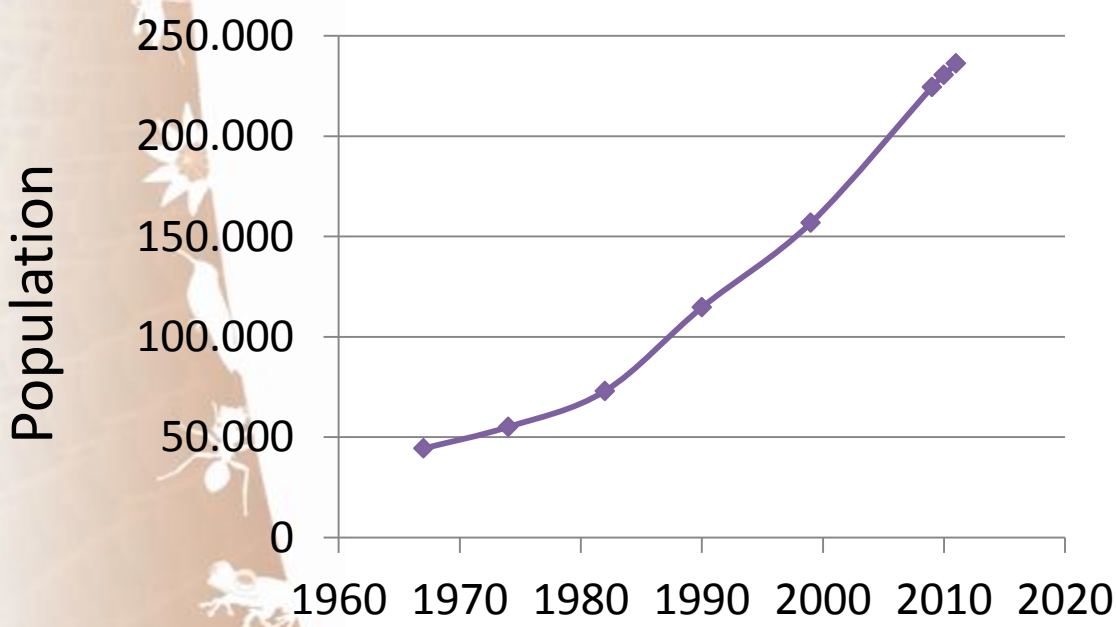
http://www.fsd2015.ukzn.ac.za/




Guiana Shield
Outliers of Shield sometimes included
Venezuela
Guyana
Colombia
Surinam
Fr. Guiana
Brazil
0
500
1,000 Km

French Guiana

A long history and knowledge on engineering, tropical medicine, tropical forestry, and evolutionary ecology



http://www.labex-ceba.fr

laboratoire d'excellence

centre d'étude de la biodiversité amazonienne

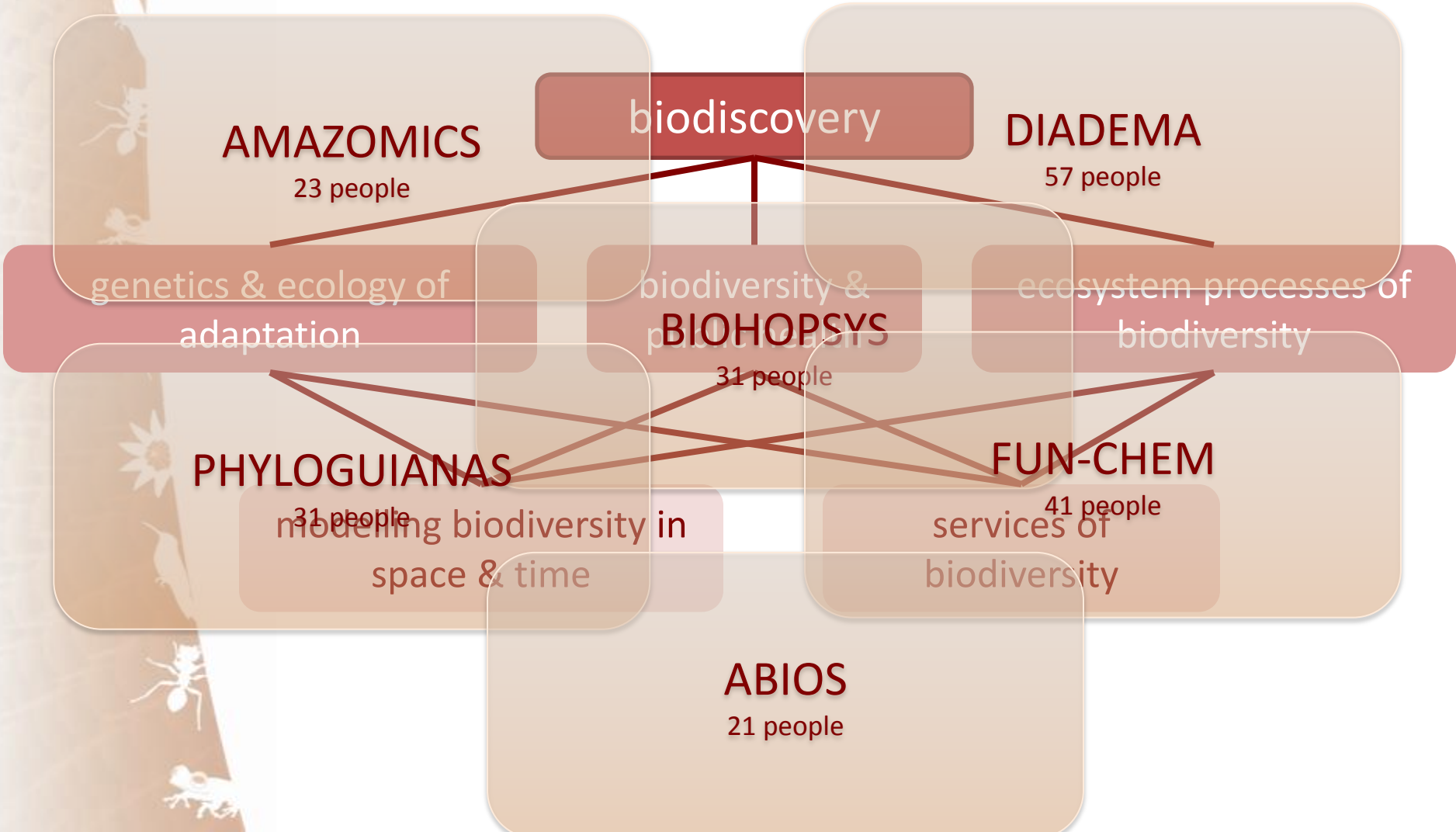
Long-term funding (2011-2019)

Attractivity, excellence, transdisciplinarity

ceba: objectives

- Build a research environment on tropical ecosystems to promote research on biodiversity.
- Crystallize a vibrant network of researchers, all actively involved in biodiversity research in Amazonia (taxonomy, ecology, evolution, biogeochemistry, biomedical sciences, analytical chemistry, social sciences)
- Foster long-term research capacity building in France and in Europe, and strengthen relationships with South American partners.

Science plan



Annual calls for proposals (next deadline 23 jan 2015)

Open to all teams outside of the lab

please apply

http://www.labex-ceba.fr

Hyperdominance in the Amazonian Tree Flora

Hans ter Steege,[1,2]* Nigel C. A. Pitman,[3,4] Daniel Sabatier,[5] Christopher Baraloto,[6] Rafael P. Salomão,[7] Juan Ernesto Guevara,[8] Oliver L. Phillips,[9] Carolina V. Castilho,[10] William E. Magnusson,[11] Jean-François Molino,[5] Abel Monteagudo,[12] Percy Núñez Vargas,[13] Juan Carlos Montero,[14,11] Ted R. Feldpausch,[9,15] Eurídice N. Honorio Coronado,[16,9] Tim J. Killeen,[17] Bonifacio Mostacedo,[18] Rodolfo Vasquez,[12] Rafael L. Assis,[11,19] John Terborgh,[3] Florian Wittmann.[20] Ana Andrade.[21] William F. Laurance.[22] Susan G. W. Laurance.[22]

We compiled stem density and species abundance data from 1170 tree inventory plots across the Amazon (Fig. 1), well distributed among all regions and major forest types (table S1 and figs. S1 to S3), to generate basin-wide estimates of the abundance, frequency, and spatial distribution of thousands of Amazonian tree species.

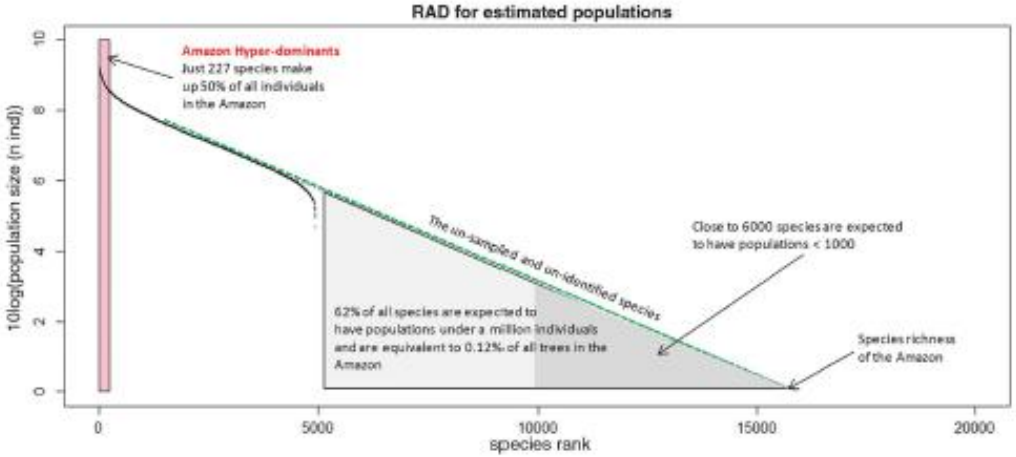
Results

A Rank-Abundance Distribution for Amazonian Trees

The plots contained a total of 4962 valid species, 810 genera, and 131 families of trees [free-

www.sciencemag.org SCIENCE VOL 342 18 OCTOBER 2013

Fig. 1. A map of Amazonia showing the location of the 1430 ATDN plots that contributed data to this paper. The white polygon marks our delimitation of the study area [with subregions after (*33*)] and consists of 567 1°-grid cells (area = 6.29 million km²). Orange circles indicate plots on terra firme; blue squares, plots on seasonally or permanently flooded terrain (várzea, igapó, and swamp); yellow triangles, plots on white-sand podzols; gray circles, plots only used for tree-density calculations. Background is from Visible Earth (*52*). CA, central Amazonia; EA, eastern Amazonia; GS, Guyana Shield; SA, southern Amazonia; WAN, northern part of western Amazonia; WAS, southern part of western Amazonia. More details are shown in figs. S1 to S3.



Tectonic-driven climate change and the diversification of angiosperms

Anne-Claire Chaboureau[a,1], Pierre Sepulchre[a], Yannick Donnadieu[a], and Alain Franc[b]

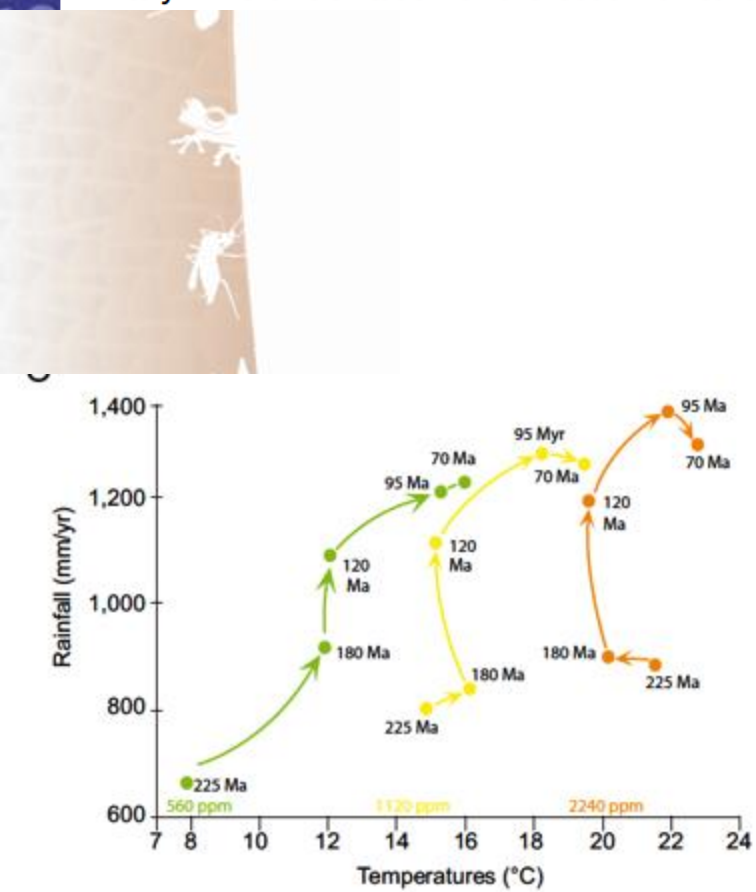
[a]Laboratoire des Sciences du Climat et de l'Environnement, Unité Mixte, Centre National de la Recherche Scientifique–Commissariat à l'Energie Atomique–Université de Versailles Saint-Quentin-en-Yvelines, 91191 Gif-sur-Yvette, France; and [b]Unité Mixte de Recherche Biodiversité, Gènes et Communautés, Institut National de la Recherche Agronomique, 33612 Cestas, France

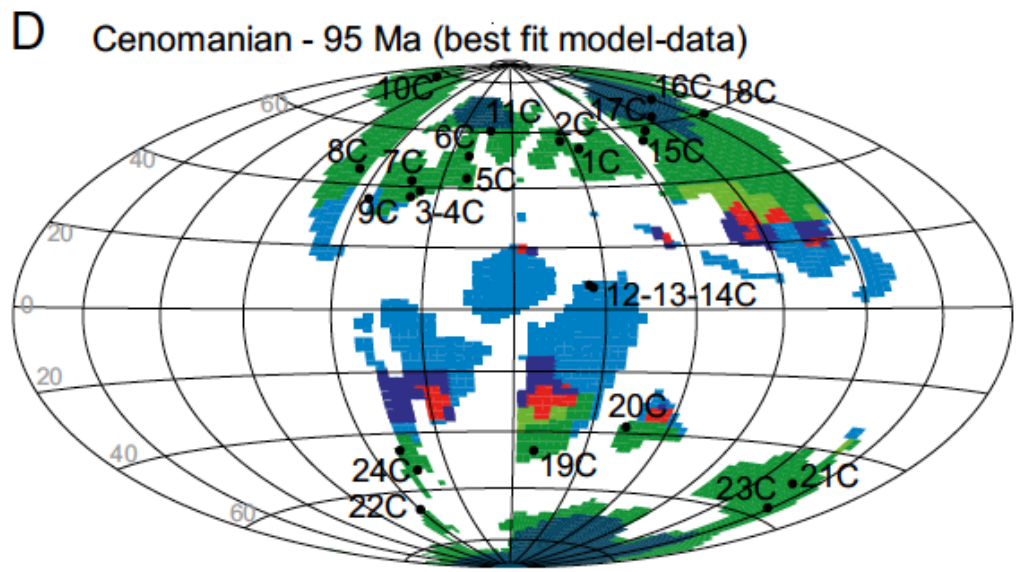
Edited by Robert E. Dickinson, The University of Texas at Austin, Austin, TX, and approved August 1, 2014 (received for review December 23, 2013)

In 1879, Charles Darwin characterized the sudden and unexplained rise of angiosperms during the Cretaceous as an "abominable mystery." The diversification of this clade marked the beginning of

covers the large uncertainties of pCO_2 estimates for these geological periods.

To validate our paleoclimatic experiments, the geographical





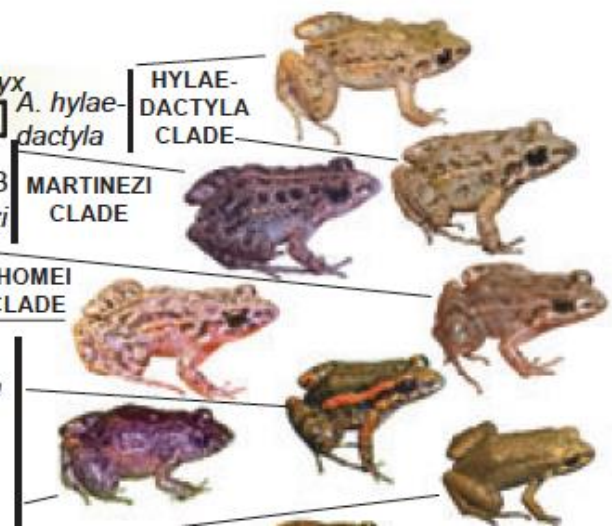
Journal of Biogeography (*J. Biogeogr.*) (2014) **41**, 855–870

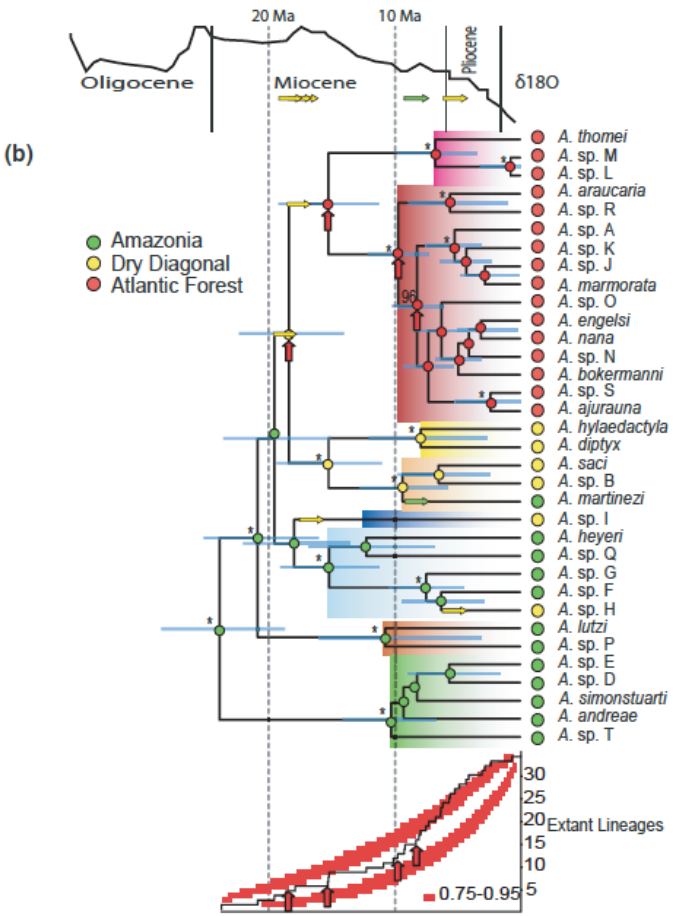
ORIGINAL ARTICLE

Species delimitation, patterns of diversification and historical biogeography of the Neotropical frog genus *Adenomera* (Anura, Leptodactylidae)

Antoine Fouquet[1,2]*, Carla Santana Cassini[3], Célio Fernando Baptista Haddad[3], Nicolas Pech[4] and Miguel Trefaut Rodrigues[2]

Results Our conservative delineation identified 31 Confirmed Candidate Sp cies (four remaining unconfirmed) representing a 94% increase in species ric ness. The biogeographical analysis suggested an Amazonian origin *Adenomera* with as many as three dispersals to the DD and one to the AF du ing the Miocene. These dispersals were associated with habitat shifts from fo est towards open habitats.





Health programs

Active projects on the epidemiological monitoring, ecosystemic context, and chemical resistance on

- Malaria
- Leishmaniosis
- Chagas disease
- Buruli ulcer
- Toxoplasmosis
- Histoplasmosis

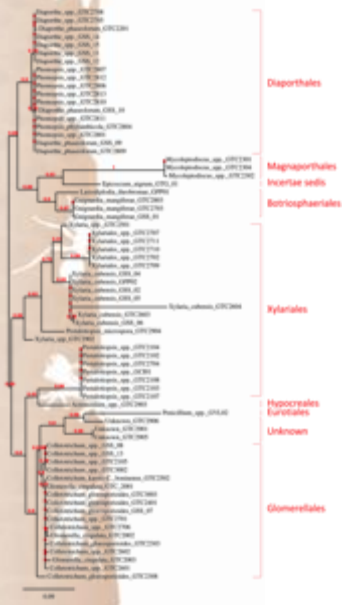
Institut Pasteur

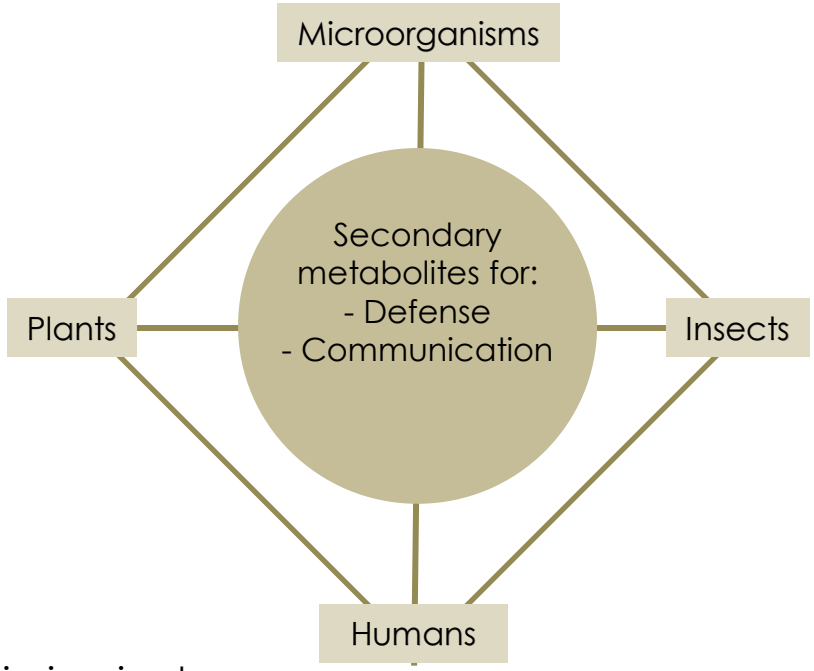
Universite des Antilles et de la Guyane

IRD Institut de recherche pour le développement

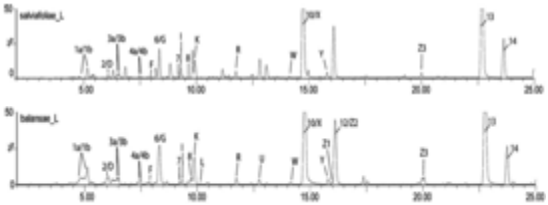
Chemistry of natural products

Genetic signature

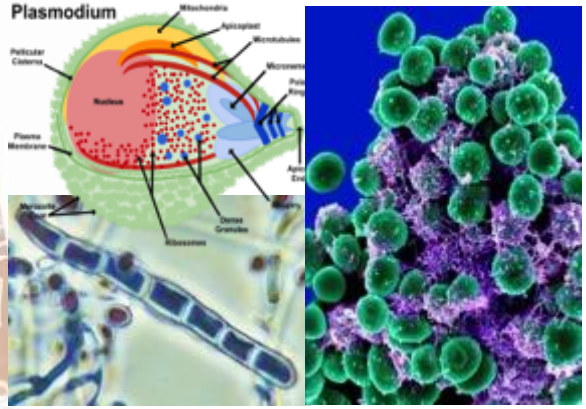




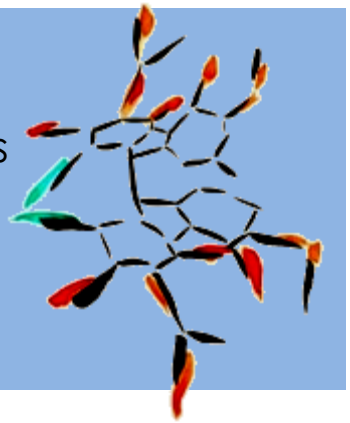
Metabolomic signature



Bio-inspired biological activities

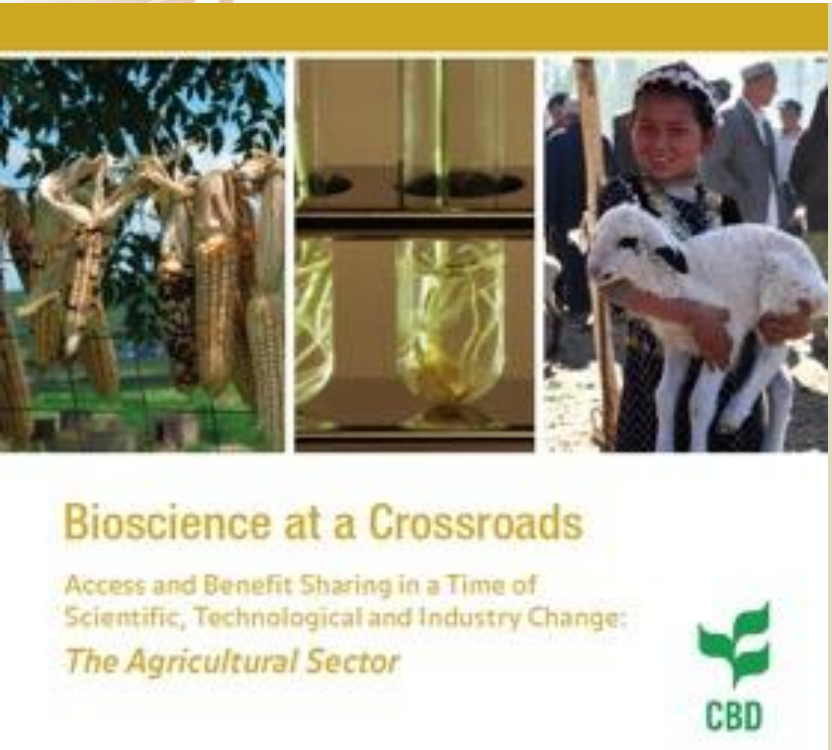


Bioactive <u>functional</u> metabolites



D Stien, Oct 2014

Coping with biodiversity in evolving legal and political frameworks



Access and Benefit Sharing

- Access needs to be consensual, realistic, flexible to be applicable and fruitful for both parties
- Companies & academic researchers who invest in research must get legal security
- Without research investment, no benefice and therefore no benefit sharing
- Access should be facilitated for the fair, equitable benefit of all (providers, industries, patients) and biodiversity preservation

Canopy Permanent Access System (COPAS)

New eddy-flux tower (Nouraflux)
October 2014

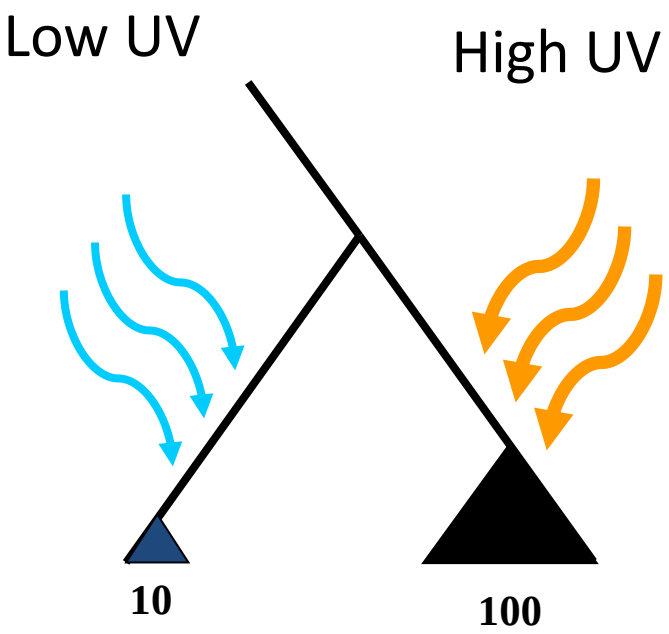
Recent advances in phylogenomics of some Neotropical woody plant families

Why are the tropics so diverse?

Tropics as a cradle for diversification

More UV irradiance ➔ higher mutation rate ➔ higher diversification rates

Armen Takhtajan
(1910-2009)



Tropics as a museum for diversity

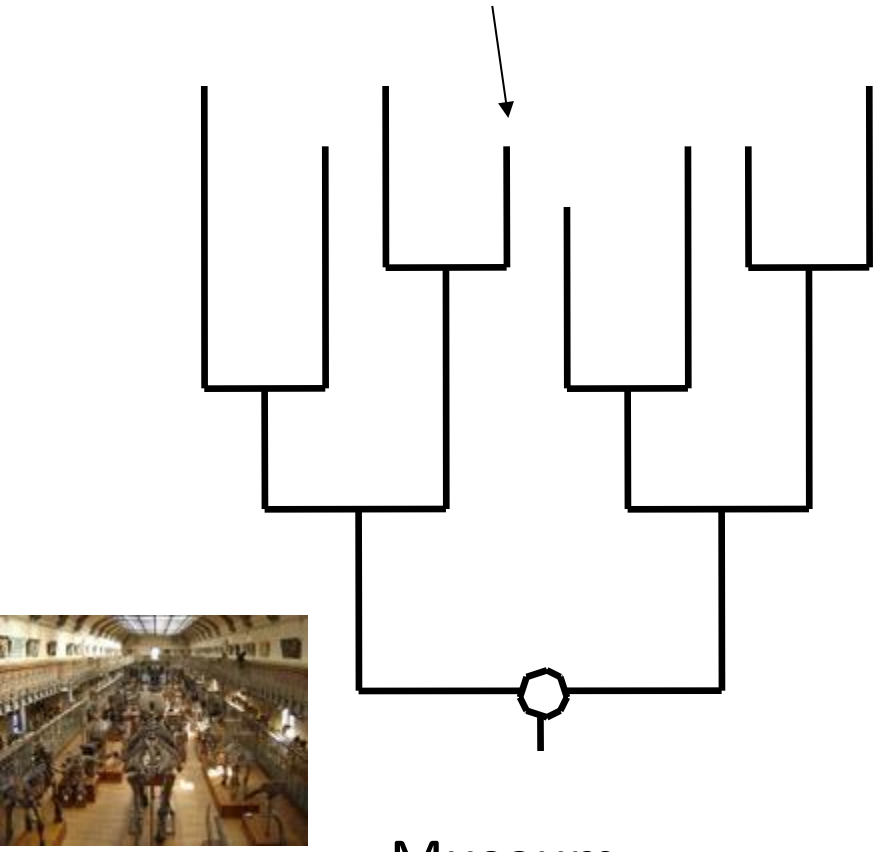
Tropical Nature (1878)

Alfred Russel Wallace
1823-1913

Phylogenies provide a crucial information on the tempo of diversification

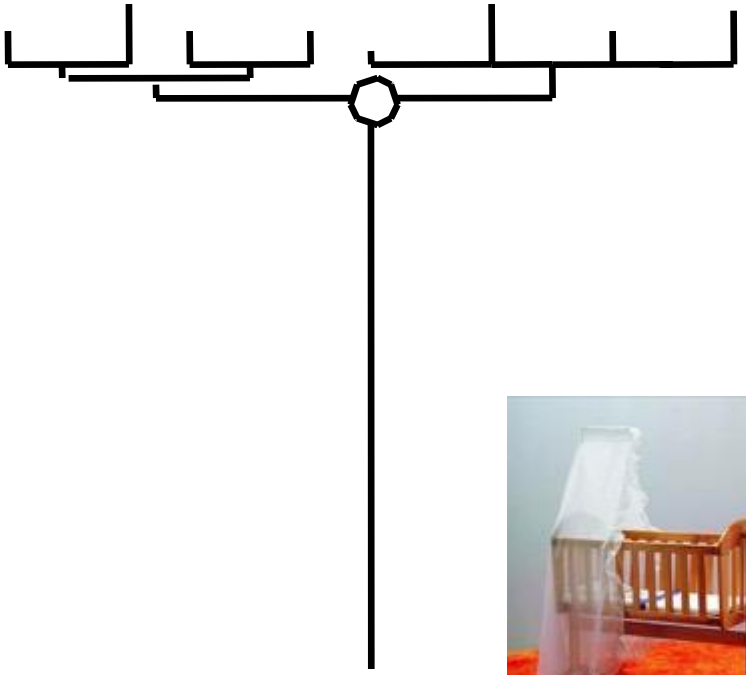
Only extant taxa are usually sampled

Branch length corresponds to the most recent common ancestor in a lineage



Museum

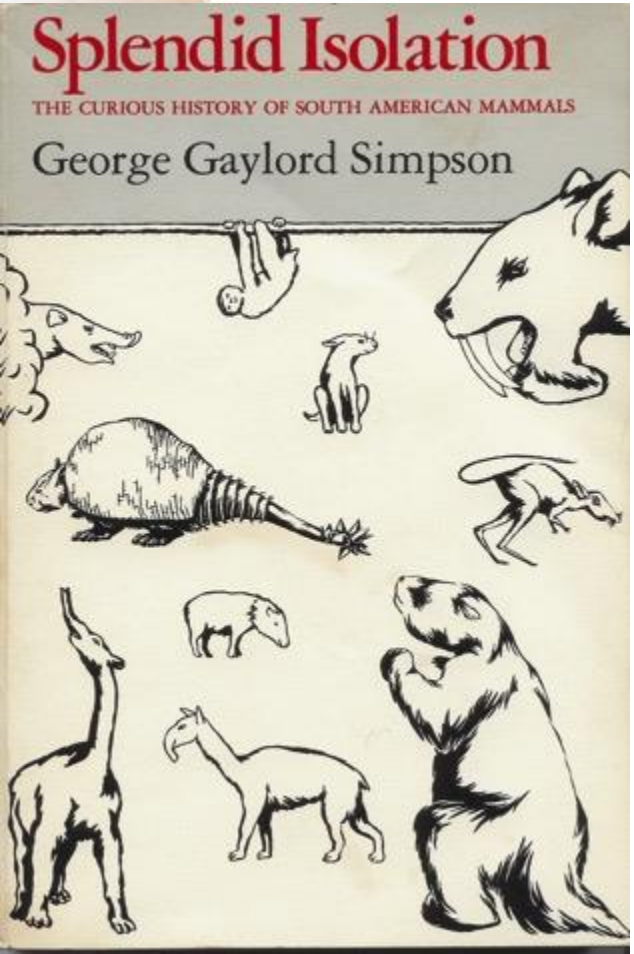
Time

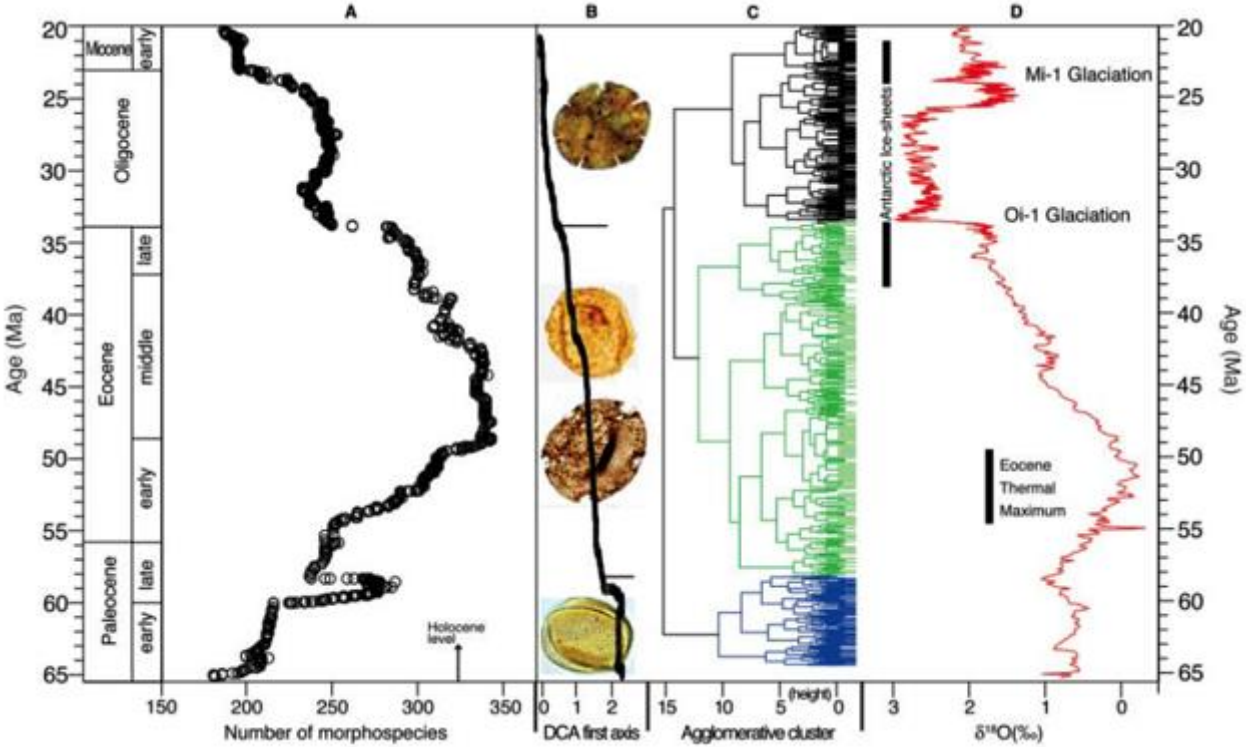


Cradle

Rate of change calibrated using the fossil record

Support for the museum hypothesis



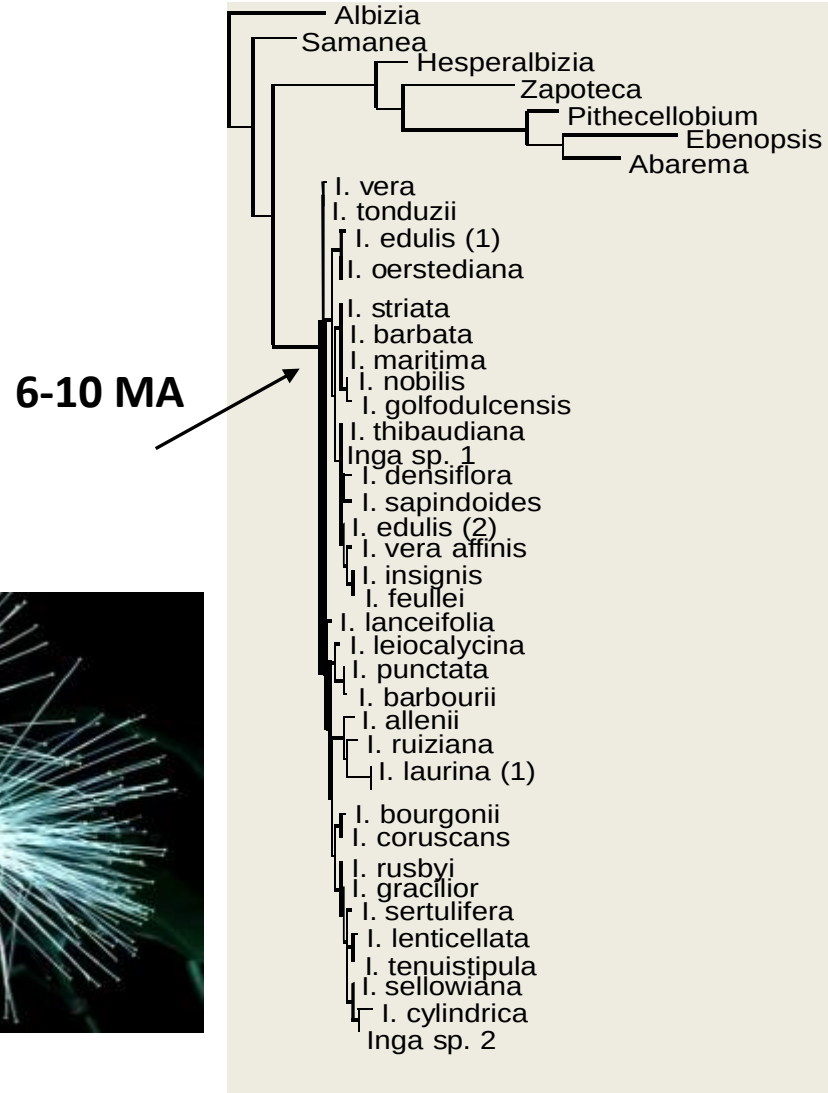


Cenozoic Plant Diversity in the Neotropics

Carlos Jaramillo,[1] Milton J. Rueda,[2] Germán Mora[3]

www.sciencemag.org SCIENCE VOL 311 31 MARCH 2006

Support for the cradle hypothesis

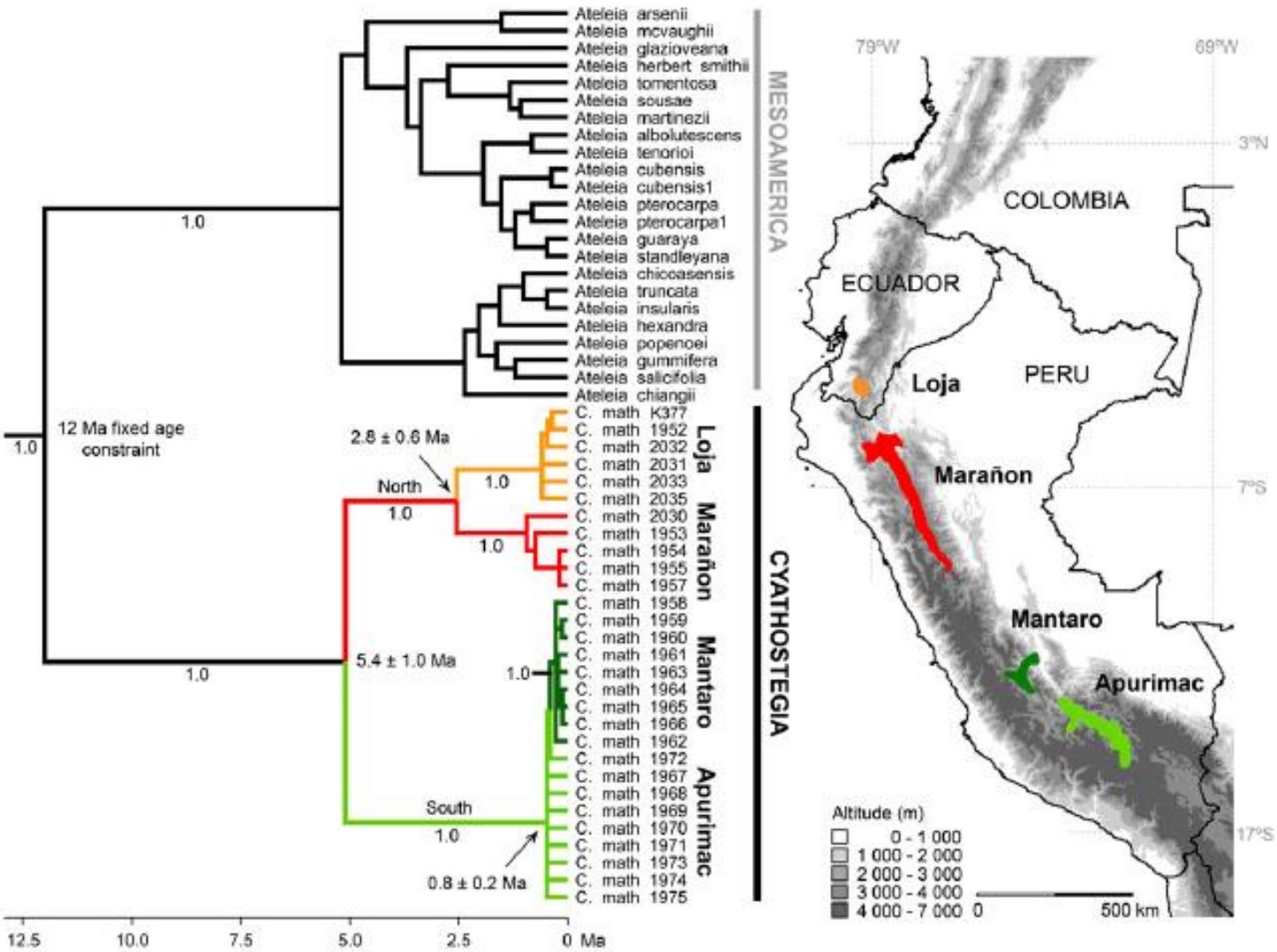


Rapid Diversification of a Species-Rich Genus of Neotropical Rain Forest Trees

James E. Richardson,[1,2] R. Toby Pennington,[1*] Terence D. Pennington,[3] Peter M. Hollingsworth[1]

21 SEPTEMBER 2001 VOL 293 SCIENCE www.sciencemag.org

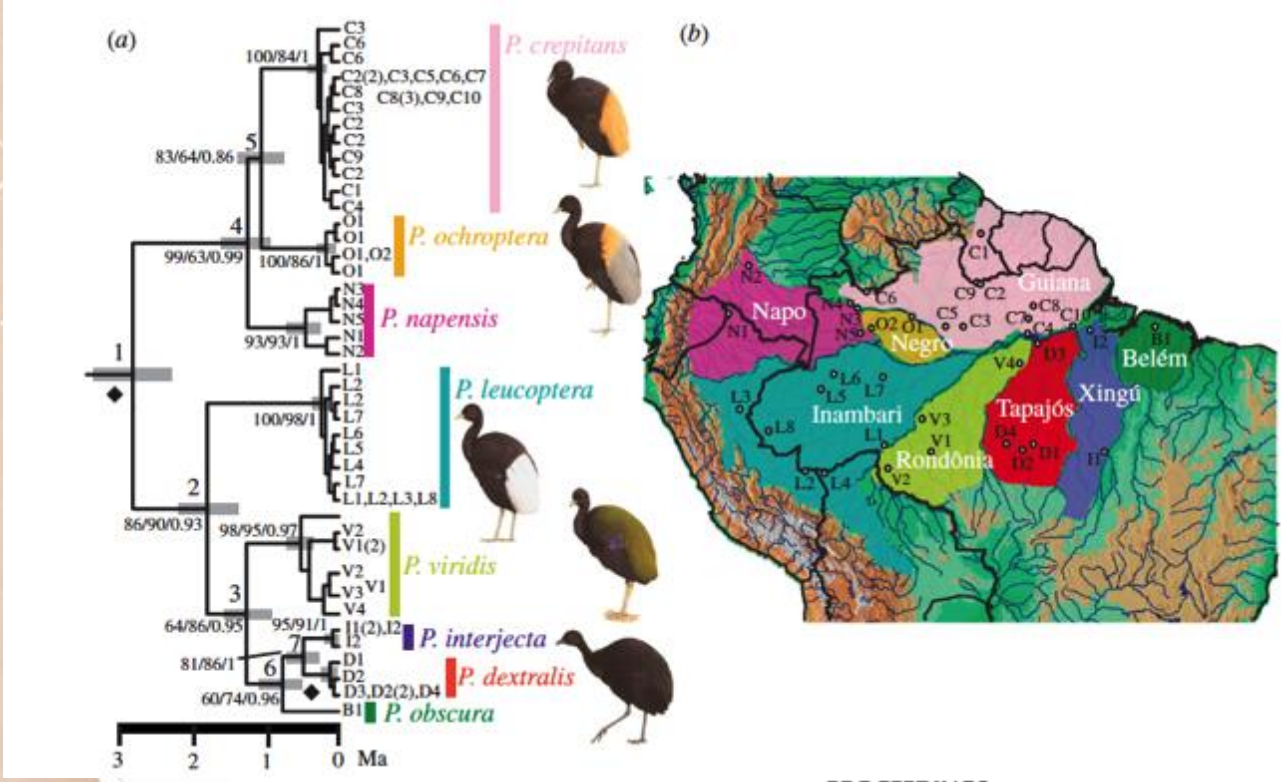
Fleurs de Cyathostegia



The story of *Cyathostegia*.

Pennington et al. PNAS 2010

Support for the cradle hypothesis



PROCEEDINGS OF THE ROYAL SOCIETY B

Proc. R. Soc. B (2012) 279, 681–689
doi:10.1098/rspb.2011.1120
Published online 27 July 2011

A palaeobiogeographic model for biotic diversification within Amazonia over the past three million years

Camila C. Ribas[1,2,*], Alexandre Aleixo[3], Afonso C. R. Nogueira[4], Cristina Y. Miyaki[5] and Joel Cracraft[2]

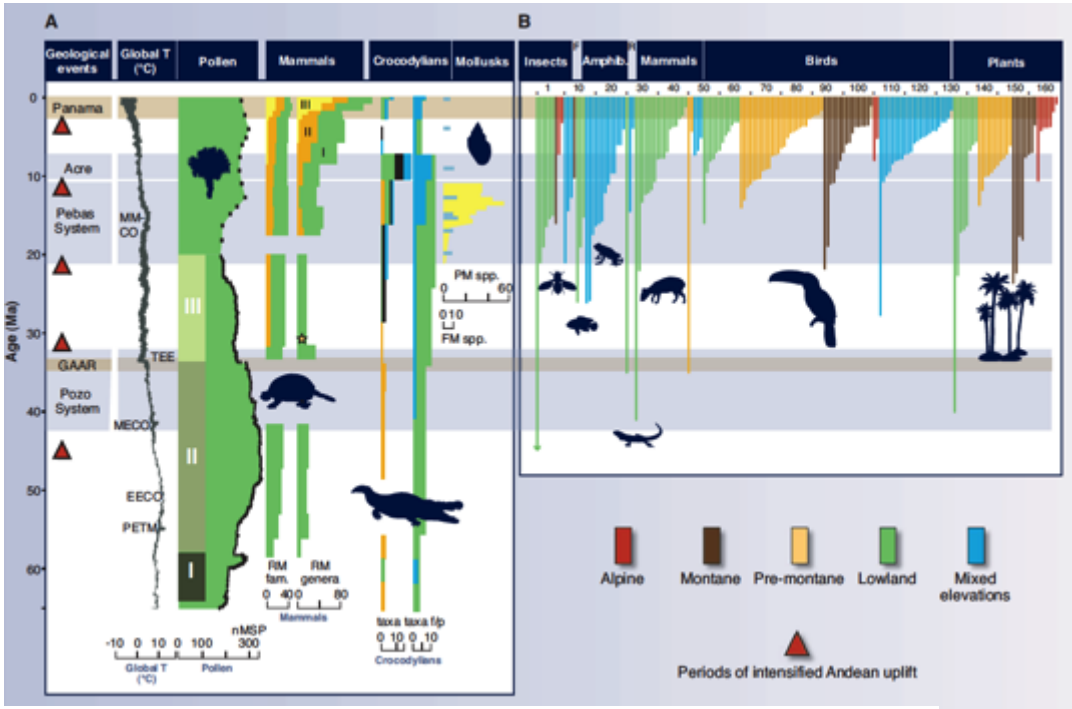
A necessarily complex model: role of intracontinental vicariance and orogeny

NEOTROPICAL FLORISTIC DIVERSITY: PHYTOGEOGRAPHICAL CONNECTIONS BETWEEN CENTRAL AND SOUTH AMERICA, PLEISTOCENE CLIMATIC FLUCTUATIONS, OR AN ACCIDENT OF THE ANDEAN OROGENY?[1,2]

ALWYN H. GENTRY[3]

The interchange of plant species between North and South America has been a major factor in determining the Neotropical phytogeographical patterns observed today. Although this has long been realized, recent historical geological evidence as well as increasing knowledge of today's distributional patterns now makes possible a more thorough analysis of how these patterns originated. This paper briefly reviews the geological background, summarizes the composition of the extant Neotropical flora, points out the striking ecological consistency of many taxa and life forms, and suggests how some of the present phytogeographical patterns have developed from the interplay of these factors.

AH Gentry, Ann Miss Bot Garden, 1982



Amazonia Through Time: Andean Uplift, Climate Change, Landscape Evolution, and Biodiversity

C. Hoorn,[1*] F. P. Wesselingh,[2] H. ter Steege,[3] M. A. Bermudez,[4] A. Mora,[5] J. Sevink,[1] I. Sanmartín,[6] A. Sanchez-Meseguer,[6] C. L. Anderson,[6] J. P. Figueiredo,[7] C. Jaramillo,[8] D. Riff,[9] F. R. Negri,[10] H. Hooghiemstra,[1] J. Lundberg,[11] T. Stadler,[12] T. Särkinen,[13] A. Antonelli[14*†]

www.sciencemag.org SCIENCE VOL 330 12 NOVEMBER 2010

Questions

1. Have predominantly Neotropical plant families originated in situ?

2. Has the tempo of diversification been steady in Neotropical plant families?

3. Can major diversification events be related to environmental change events?

Most abundant tree families in Amazonia

Family	%abundance	rank	%species	rank
Fabaceae	15.3	1	16.0	1
Sapotaceae	6.1	4	4.2	5
Malvaceae	4.9	5	3.4	8
Annonaceae	3.4	11	5.8	3
Chrysobalanaceae	4.5	8	3.9	6
Lauraceae	2.7	12	6.2	2
Lecythidaceae	7.9	3	2.1	14
Moraceae	4.8	6	2.7	11
Euphorbiaceae	4.4	9	2.9	10
Arecaceae	9.4	2	1.4	19

RESEARCH ARTICLE

Hyperdominance in the Amazonian Tree Flora

Hans ter Steege,[1,2*] Nigel C. A. Pitman,[3,4] Daniel Sabatier,[5] Christopher Baraloto,[6]

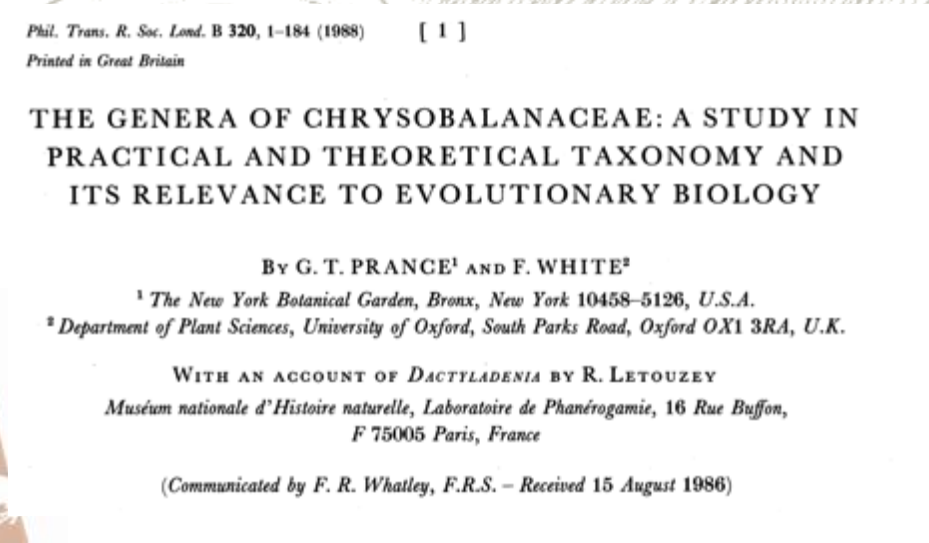
We compiled stem density and species abundance data from 1170 tree inventory plots across the Amazon (Fig. 1), well distributed among all regions and major forest types (table S1 and figs. S1 to S3), to generate basin-wide estimates of the abundance, frequency, and spatial distribution of thousands of Amazonian tree species.

Results

Published by AAAS

Chrysobalanaceae

- Mid-sized family with ca 500 species, 80% of them in the Neotropics
- Taxonomy of the family has been carefully researched since the 1960s



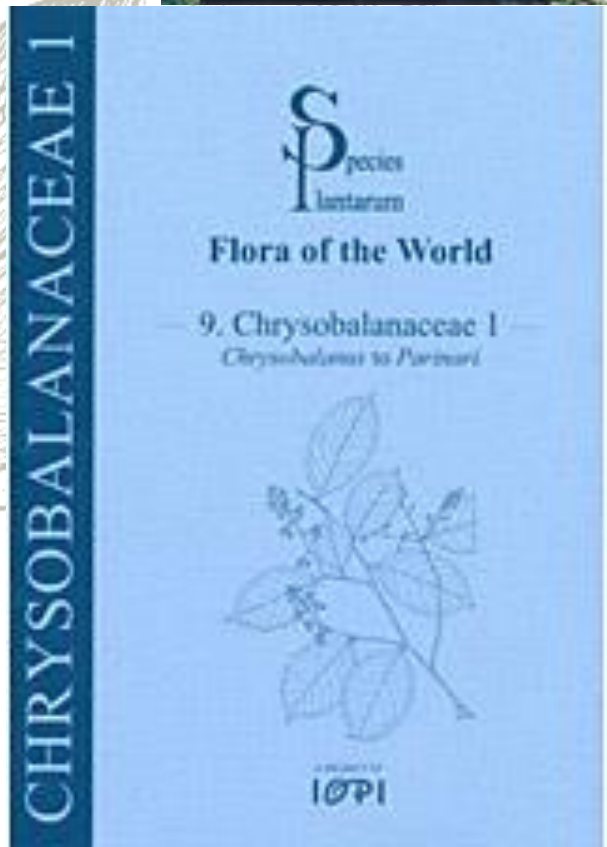
Phil. Trans. R. Soc. Lond. B **320**, 1–184 (1988) [1]
Printed in Great Britain

THE GENERA OF CHRYSOBALANACEAE: A STUDY IN PRACTICAL AND THEORETICAL TAXONOMY AND ITS RELEVANCE TO EVOLUTIONARY BIOLOGY

By G. T. PRANCE[1] and F. WHITE[2]
[1] *The New York Botanical Garden, Bronx, New York* 10458–5126, *U.S.A.*
[2] *Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX*1 3*RA, U.K.*

With an account of *Dactyladenia* by R. Letouzey
Muséum nationale d'Histoire naturelle, Laboratoire de Phanérogamie, 16 *Rue Buffon, F* 75005 *Paris, France*

(*Communicated by F. R. Whatley, F.R.S. – Received* 15 *August* 1986)



LINNEAN SOCIETY BOTANICAL Journal

Botanical Journal of the Linnean Society, 2013, **171**, 19–37. With 3 figures

Origin and evolution of Chrysobalanaceae: insights into the evolution of plants in the Neotropics

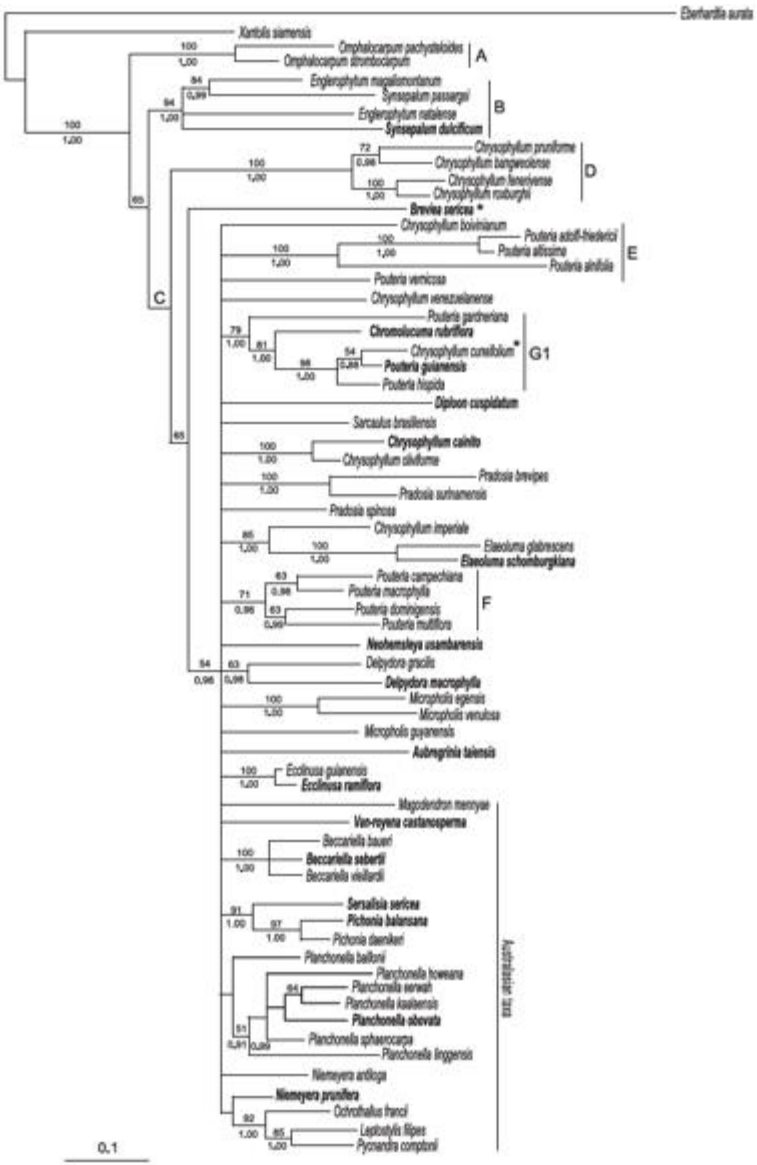
LÉA BARDON[1], JULIETTE CHAMAGNE[1,2], KYLE G. DEXTER[1,3], CYNTHIA A. SOTHERS[4], GHILLEAN T. PRANCE[4] and JÉRÔME CHAVE[1*]

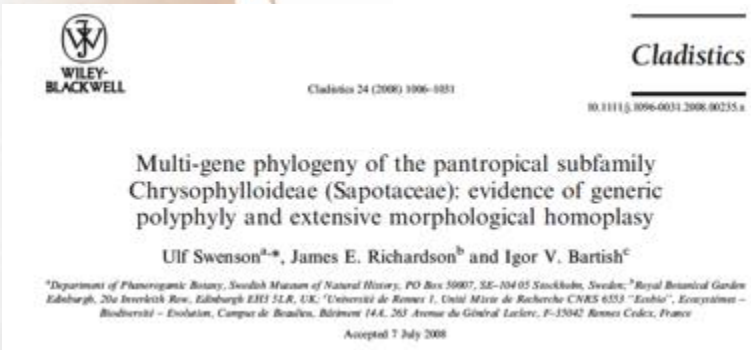
18/73 nodes supported
(PP > 80%) 24% of the nodes

Basal nodes poorly resolved

Sapotaceae:Chrysophylloideae

- ➔ Ca 1200 species; ca 600 species in subfamily Chrysophylloideae
- ➔ Remarkably species-rich in the French Guiana tree flora
- ➔ Little support for phylogenetic relations at the base of tree





WILEY-BLACKWELL

Cladistics 24 (2008) 1006–1031

Cladistics

10.1111/j.1096-0031.2008.00235.x

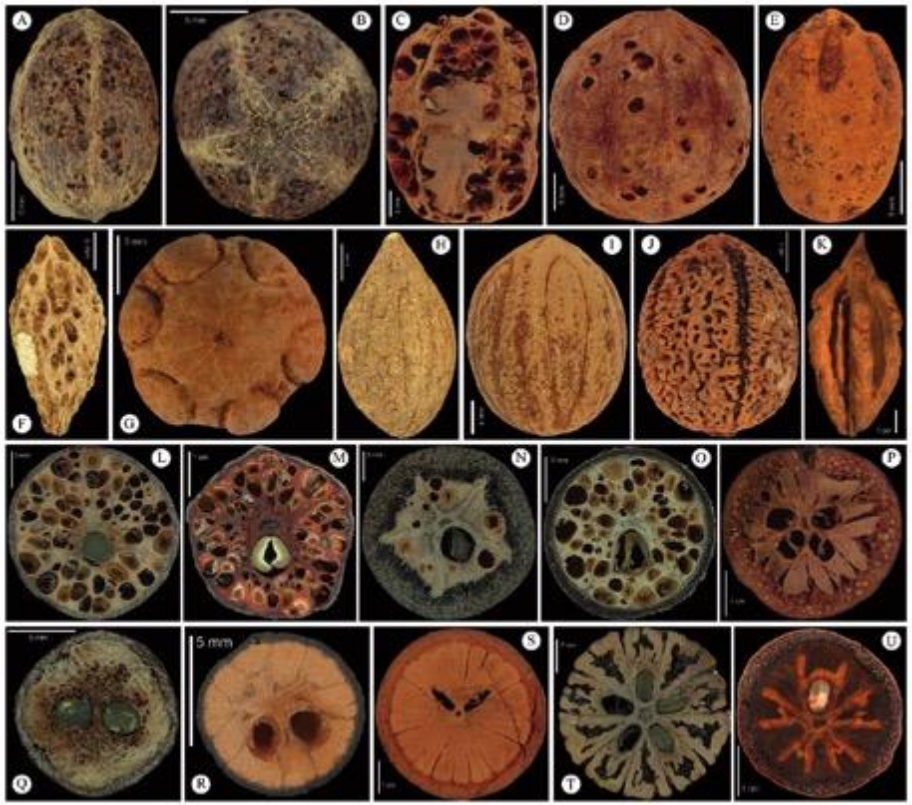
Multi-gene phylogeny of the pantropical subfamily Chrysophylloideae (Sapotaceae): evidence of generic polyphyly and extensive morphological homoplasy

Ulf Swenson[a,*], James E. Richardson[b] and Igor V. Bartish[c]

[a]Department of Phanerogamic Botany, Swedish Museum of Natural History, PO Box 50007, SE-104 05 Stockholm, Sweden; [b]Royal Botanical Garden Edinburgh, 20a Inverleith Row, Edinburgh EH3 5LR, UK; [c]Université de Rennes 1, Unité Mixte de Recherche CNRS 6553 "Ecobio", Ecosystèmes – Biodiversité – Evolution, Campus de Beaulieu, Bâtiment 14A, 263 Avenue du Général Leclerc, F-35042 Rennes Cedex, France

Accepted 7 July 2008

Humiriaceae



Ca 60 species

Excellent fossil record (by Neotropical plant families standards), recently revised

Only Neotropical (except 1 species, African)

it. J. Plant Sci. 171(4):392–408. 2010.

058-5893/2010/17104-0005$15.00 DOI: 10.1086/651229

PHYTOGEOGRAPHIC HISTORY AND PHYLOGENY OF THE HUMIRIACEAE

Fabiany Herrera,[1,*,†] Steven R. Manchester,* Carlos Jaramillo,† Bruce MacFadden,*‡ and Silane A. da Silva-Caminha†

*Department of Biology, Florida Museum of Natural History, University of Florida, Gainesville, Florida 32611, U.S.A.; †Smithsonian Tropical Research Institute, Apartado Postal 0843-03092, Balboa, Ancon, Panamá, República de Panamá; and ‡Division of Research on Learning (EHR/DRL), National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22031, U.S.A.

PNAS

Using plastid genome-scale data to resolve enigmatic relationships among basal angiosperms

Michael J. Moore[†‡], Charles D. Bell[§], Pamela S. Soltis[¶], and Douglas E. Soltis[†]

[†]Department of Botany and [¶]Florida Museum of Natural History, University of Florida, Gainesville, FL 32611; and [§]Department of Biological Sciences, University of New Orleans, New Orleans, LA 70149

Communicated by David L. Dilcher, University of Florida, Gainesville, FL, August 28, 2007 (received for review June 15, 2007)

Although great progress has been made in clarifying deep-level angiosperm relationships, several early nodes in the angiosperm branch of the Tree of Life have proved difficult to resolve. Perhaps

as sister to magnoliids, *Ceratophyllum*, or as part of a clade with magnoliids and Chloranthaceae, generally with low support (7, 12, 15, 17, 19–24). The unstable relationships exhibited among

BMC Biology *BMC Biology* 2009, **7**:84

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Research article

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Increasing phylogenetic resolution at low taxonomic levels using massively parallel sequencing of chloroplast genomes

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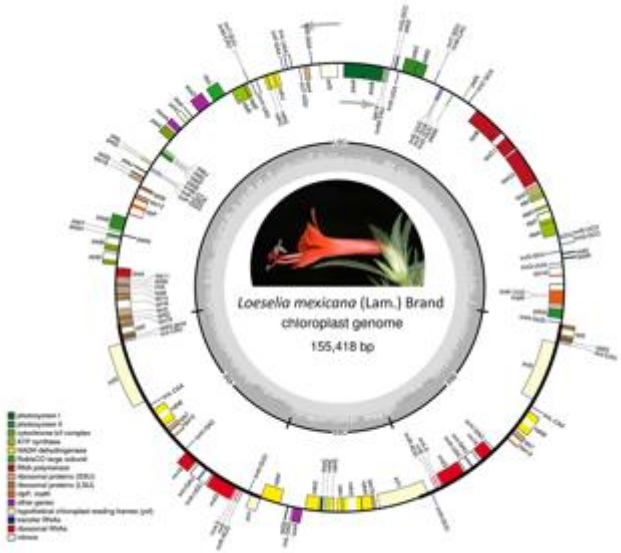
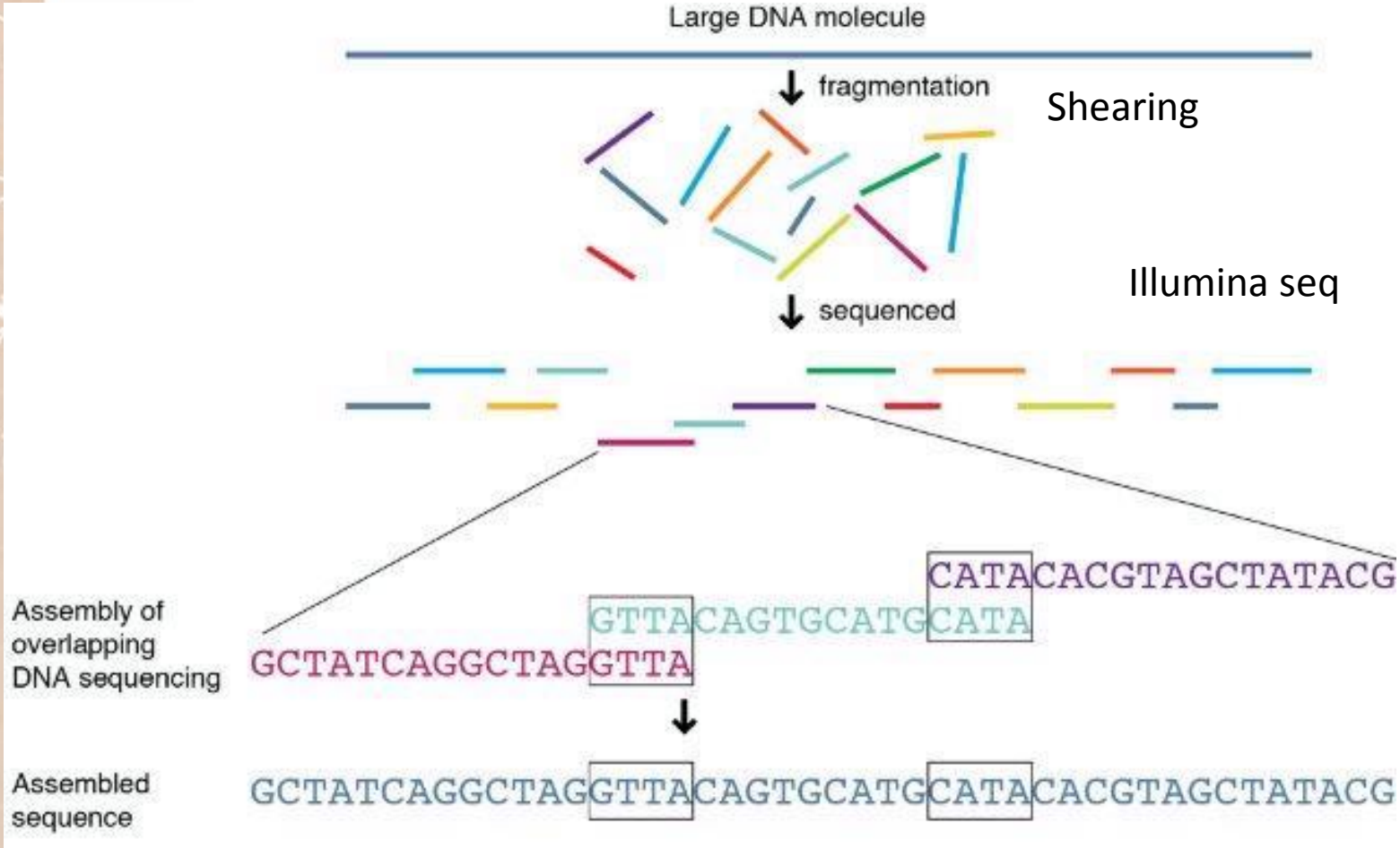


ASSEMBLING THE TREE OF THE MONOCOTYLEDONS: PLASTOME SEQUENCE PHYLOGENY AND EVOLUTION OF POALES[1]

Thomas J. Givnish,[2] Mercedes Ames,[2] Joel R. McNeal,[3] Michael R. McKain,[3] P. Roxanne Steele,[4] Claude W. dePamphilis,[5] Sean W. Graham,[6] J. Chris Pires,[4] Dennis W. Stevenson,[7] Wendy B. Zomlefer,[3] Barbara G. Briggs,[8] Melvin R. Duvall,[9] Michael J. Moore,[10] J. Michael Heaney,[11] Douglas E. Soltis,[11] Pamela S. Soltis,[12] Kevin Thiele,[13] and James H. Leebens-Mack[3]

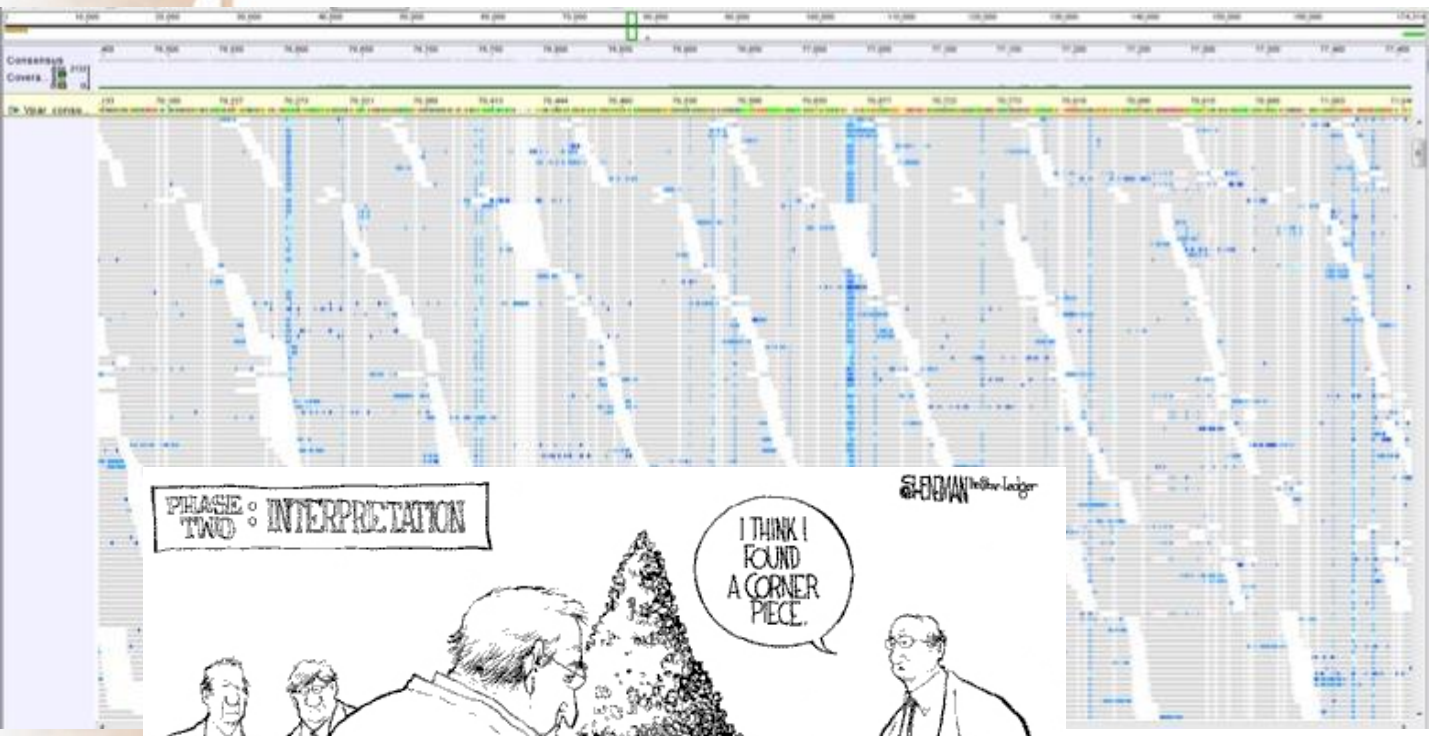
Ann. Missouri Bot. Gard. 97: 584–616. Published on 27 December 2010.

Shotgun sequencing



No plastid DNA enrichment

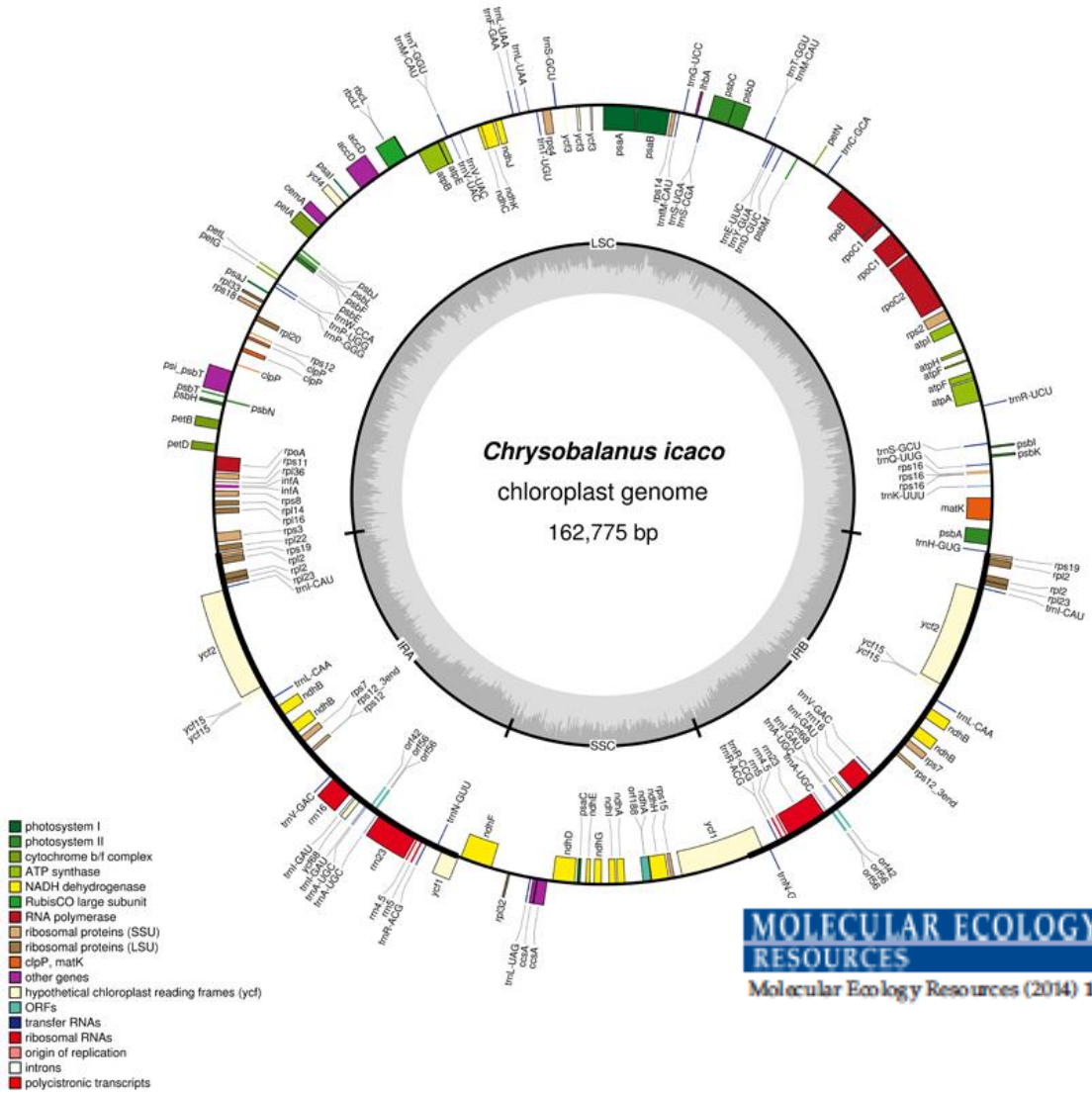
Assembling sequencing reads



Eric Coissac
Grenoble, France

Results

1. Chrysobalanaceae

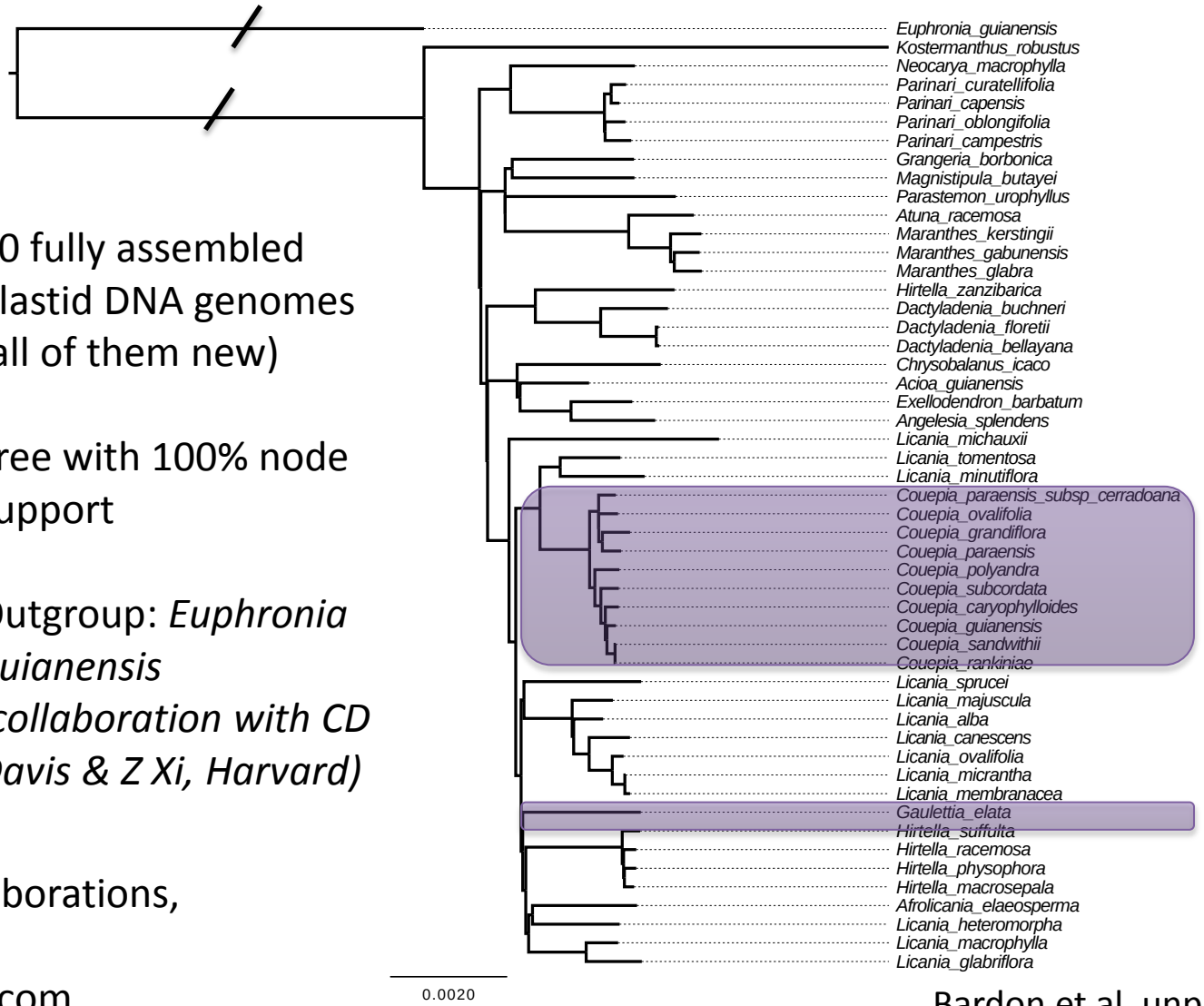


MOLECULAR ECOLOGY RESOURCES
Molecular Ecology Resources (2014) 14, 966–975
doi: 10.1111/1755-0998.12246

Genome skimming by shotgun sequencing helps resolve the phylogeny of a pantropical tree family

PIERRE-JEAN G. MALÉ,*† LÉA BARDON,* GUILLAUME BESNARD,* ERIC COISSAC,‡ FRÉDÉRIC DELSUC,§ JULIEN ENGEL,¶ EMELINE LHUILLIER,**†† CAROLINE SCOTTI-SAINTAGNE,¶ ALEXANDRA TINAUT¶ and JÉRÔME CHAVE*

Chrysobalanaceae ptDNA phylogeny



50 fully assembled plastid DNA genomes (all of them new)

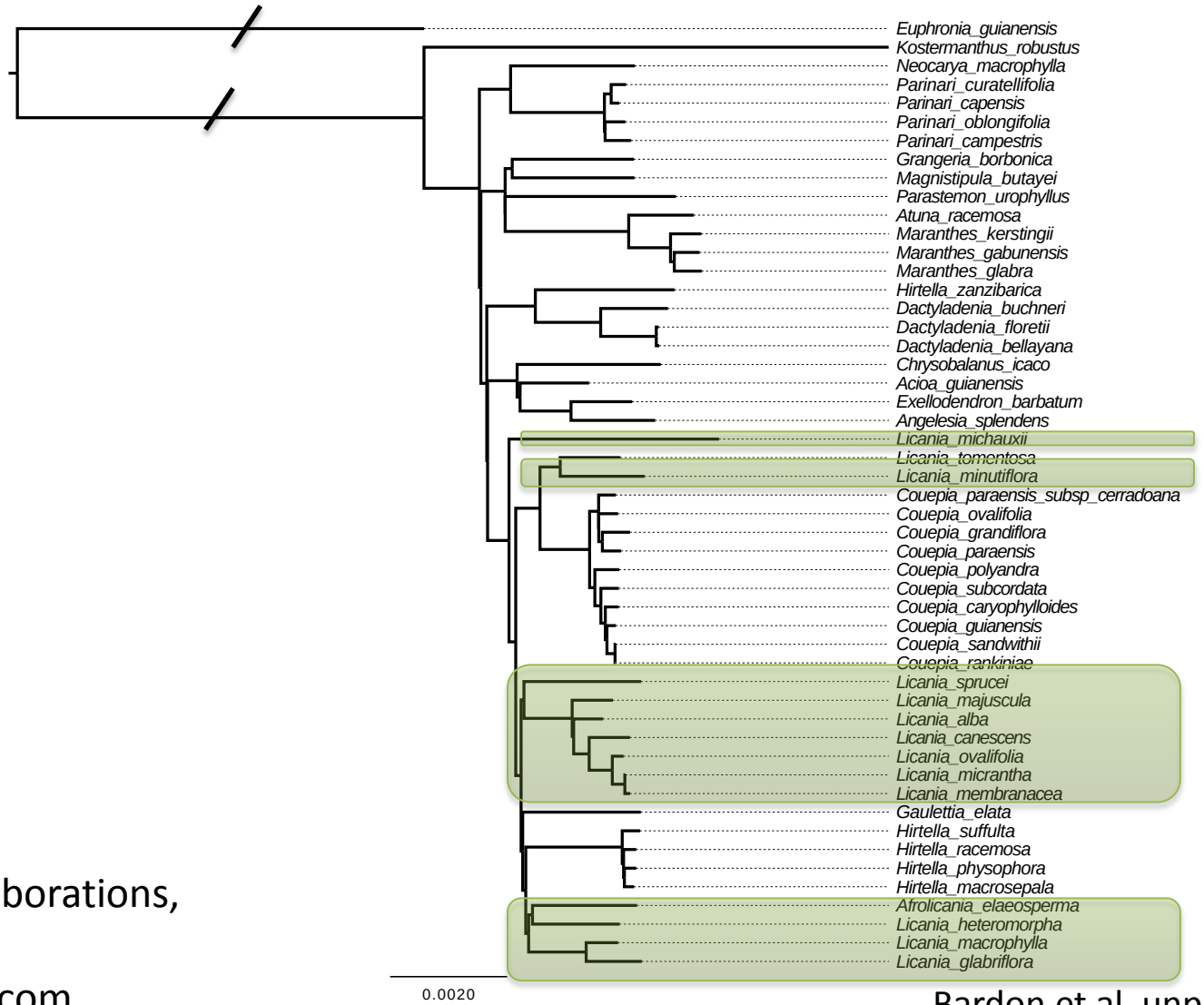
Tree with 100% node support

Outgroup: *Euphronia guianensis* *(collaboration with CD Davis & Z Xi, Harvard)*

For questions, collaborations, please contact lea.bardon@gmail.com

Bardon et al. unpublished

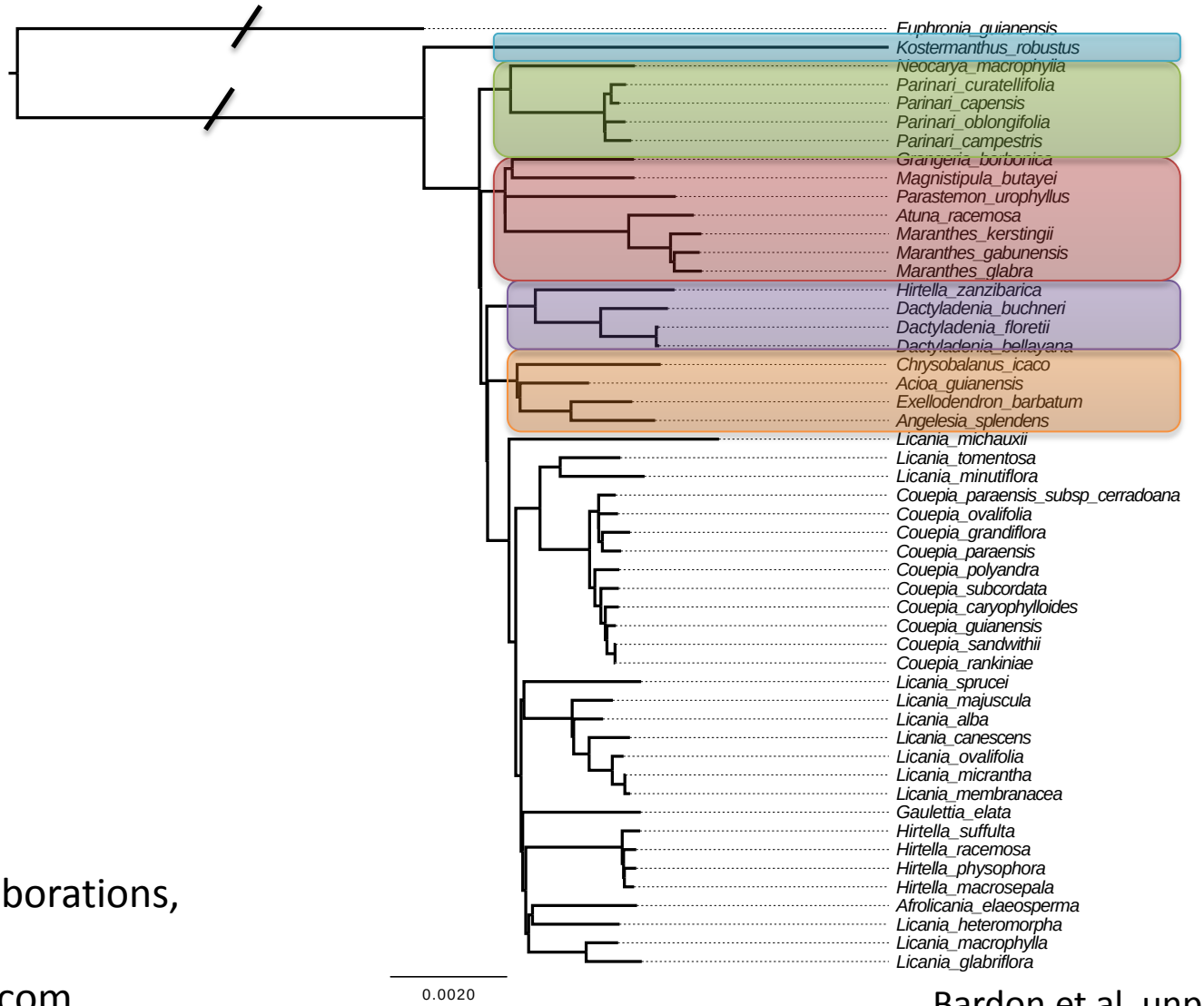
Chrysobalanaceae ptDNA phylogeny



For questions, collaborations, please contact lea.bardon@gmail.com

Bardon et al. unpublished

Chrysobalanaceae ptDNA phylogeny



For questions, collaborations, please contact lea.bardon@gmail.com

Bardon et al. unpublished

Take-home messages

1. *Couepia* is split into two genera (type 'parillo' becomes *Gaulettia* Sothers et al. 2014)

2. *Licania* is split into four genera (*Licania* ss, '*heteromorpha*' clade, '*minutiflora*' clade, *Licania michauxii*)

3. Ancestral lineage is *Kostermanthus*, followed by *Parinari* ➔ **the family originated in the paleotropics in spite of its dominance in the Neotropics**

4. The fossil record in this family is too sparse to draw firm conclusions about its tempo of diversification

Results

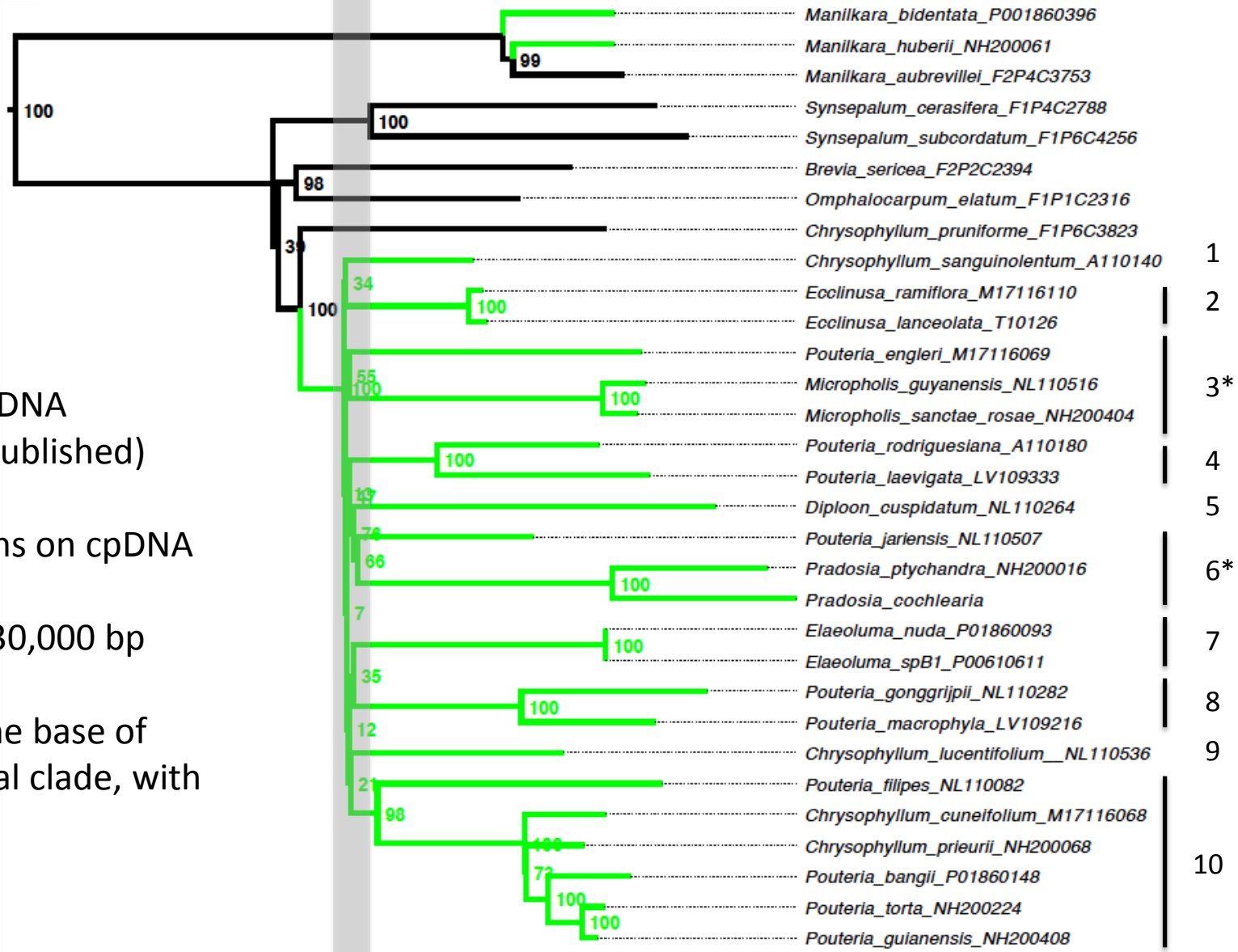
2. Sapotaceae

31 full plastid DNA genomes (unpublished)

Three partitions on cpDNA

Total length 130,000 bp

12 clades at the base of the Neotropical clade, with no support



Chave et al. unpublished

Take-home messages

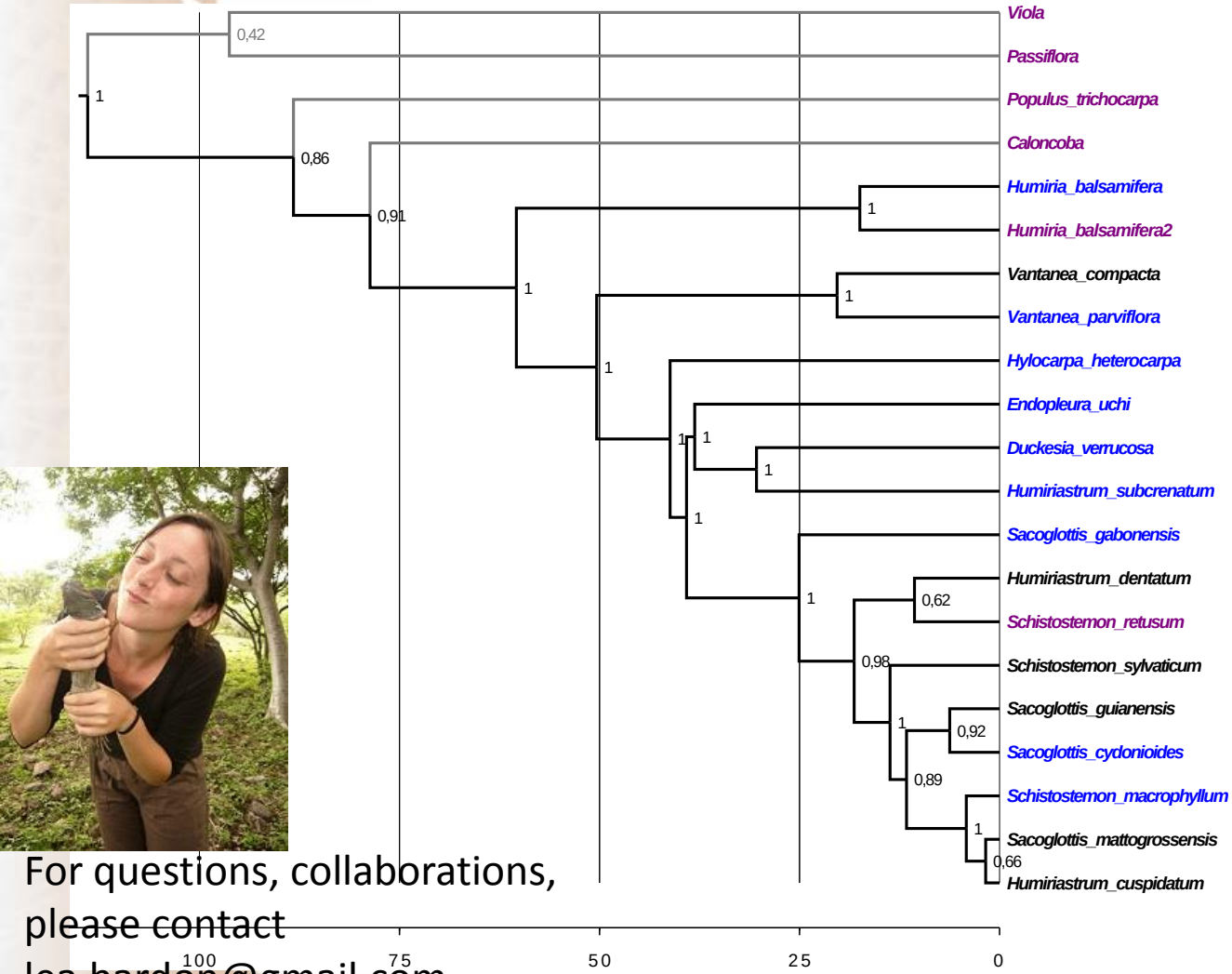
- Diversification in Sapotaceae: Chrysophylloideae is associated with a sudden burst, possibly linked to the K/T transition (65 Ma ago)

- Polyphyly in both *Chrysophyllum* and *Pouteria* is obvious, but more sampling is needed to better explore this (work in progress)

Results

3. Humiriaceae

Humiriaceae ptDNA phylogeny



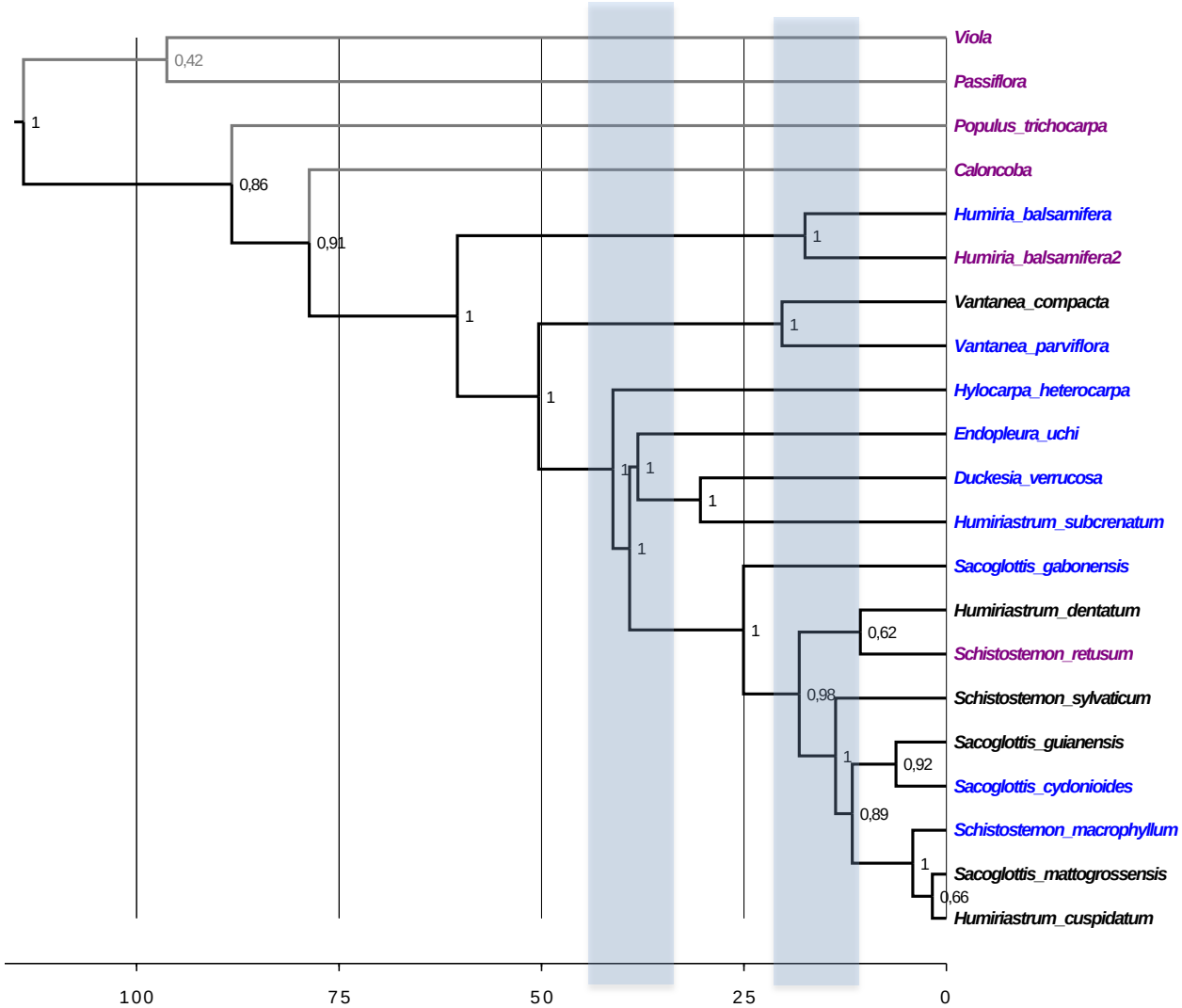
Full ptDNA (unpublished)

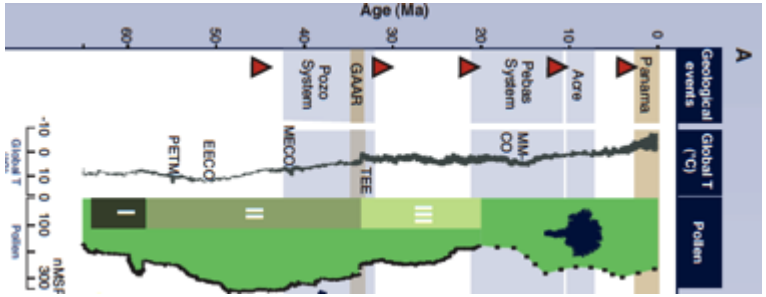
CDS of ptDNA (Xi et al. 2012)

Partial ptDNA (unpub)

For questions, collaborations, please contact lea.bardon@gmail.com

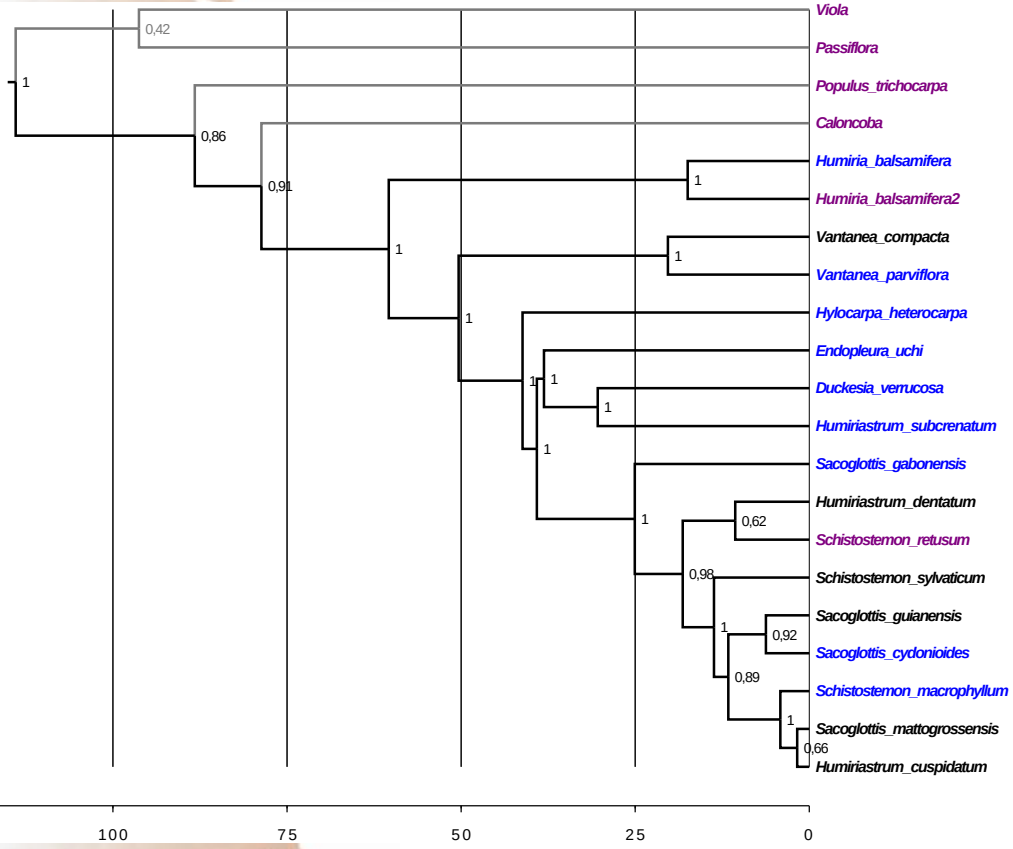
Diversification pattens



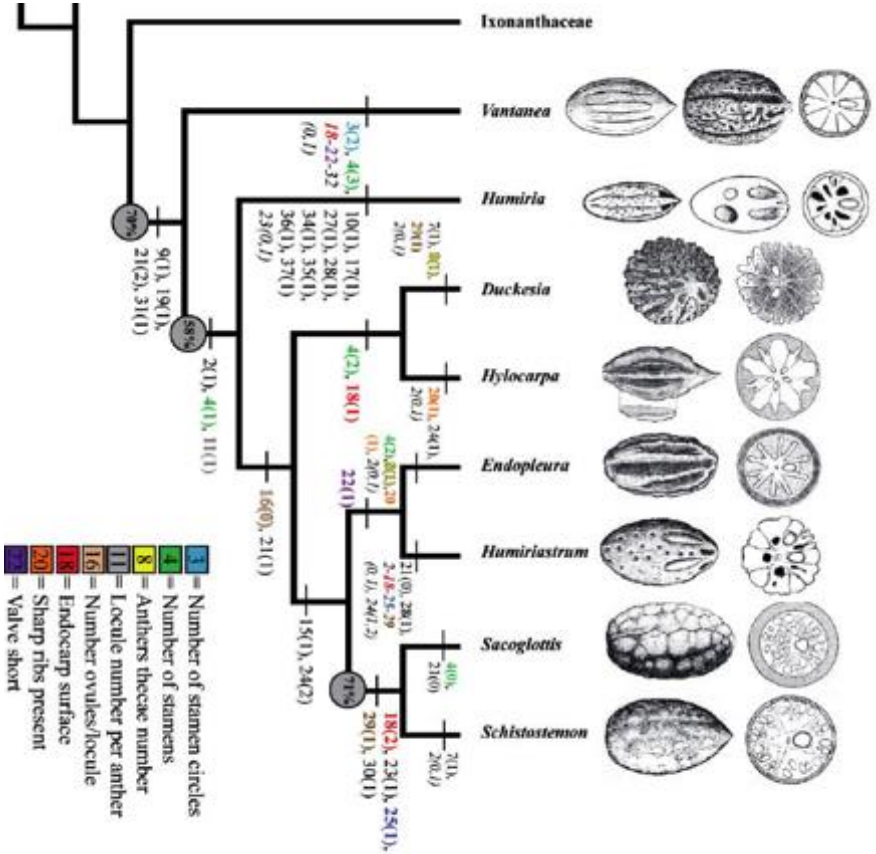


For questions, collaborations, please contact lea.bardon@gmail.com

Humiriaceae: molecular vs morphology



Bardon et al. unpublished



Herrera et al. Int J Plant Sciences (2010)

Main findings

1. Have predominantly Neotropical plant families originated in situ?

   ➔ No, Chrysobalanaceae are a clear-cut case of paleotropical origination with secondary dispersal into the Neotropics

2. Has the tempo of diversification been steady in Neotropical plant families?

   ➔ Not always, Sapotaceae:Chrysophylloideae show a surprising pattern of explosive diversification that may have coincided with the Cretaceous-Paelogene transition

3. Can major diversification events be related to environmental change events?

   ➔ Yes, in Humiriaceae stages of diversification seem to coincide with period of flooding of the Pebas system

Discussion

'the fact that the entire plastid tracks a single phylogeny is a liability in cases of introgression ("plastid capture") and incomplete lineage sorting (aka "deep coalescence").

it is not known to what degree plastid-based studies at the genus or family level may produce precise gene trees that are inaccurate as species trees. This is not a new concern (e.g., Doyle, 1992).'

TAXON 62 (2) • April 2013: 217–248

REVIEWS

Legume phylogeny and classification in the 21st century: Progress, prospects and lessons for other species-rich clades

The Legume Phylogeny Working Group[1]

Perspectives

- Completing the sampling in various regions: we'd love to collaborate with anyone interested

- Funded sequencing of several hundred Amazonian plant species in 2015

- Implementing this approach on other groups in the Guiana Shield (amphibians, opilions): strategic CEBA project

Acknowledgements

Special thanks to:

Guillaume Besnard
Juliette Chamagne
Eric Coissac
Gilles Dauby
Bruno David (laboratoire Pierre Fabre)
Charles Davis
Kyle Dexter
Roosevelt Garcia
Bernadette Grosso
Amaia Iribar
Emeline Lhuillier
Pierre-Jean Malé
Olivier Maurin
Ingrid Parmentier
Toby Pennington
Joan Pereira
Ghillean Prance
James Richardson
Daniel Sabatier
Julieth Serrano
Cynthia Sothers
Dominique Strasberg
Pierre Taberlet
Alberto Vicentini
Zhenxiang Xi
L' Association France/Sahel

SUPPORTED BY ANR


thank you
centre d'étude de la
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