
BERKELEY MYCOLOGY
A
x
a
PUTRES
CAT
1875

Reverse ecology: population genomics, divergence and adaptation

John Taylor
UC Berkeley
http://taylorlab.berkeley.edu/

Fungi and how they adapt.

What are Fungi?

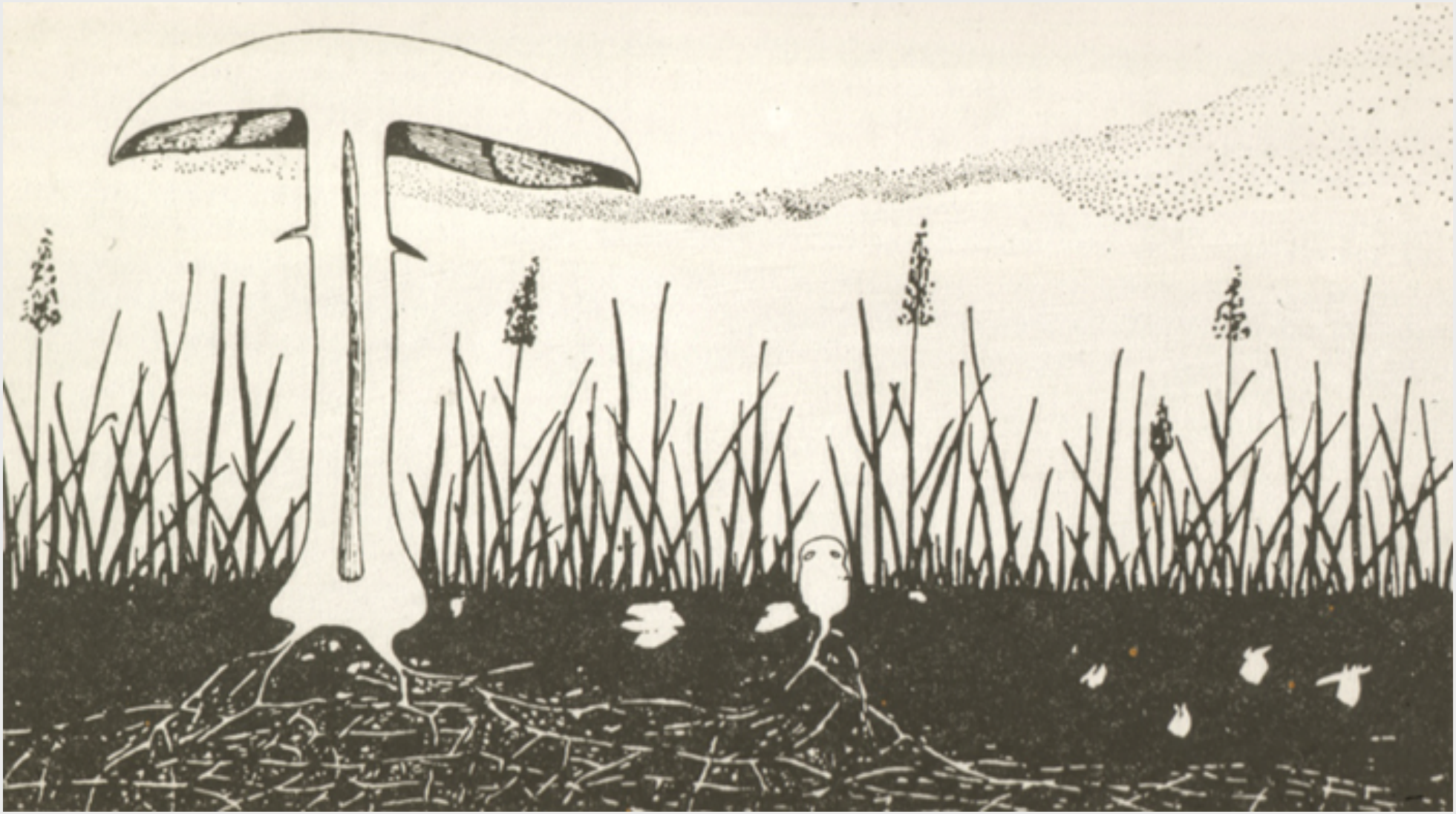
Where are Fungi in the Tree of Life?

Adaptation.

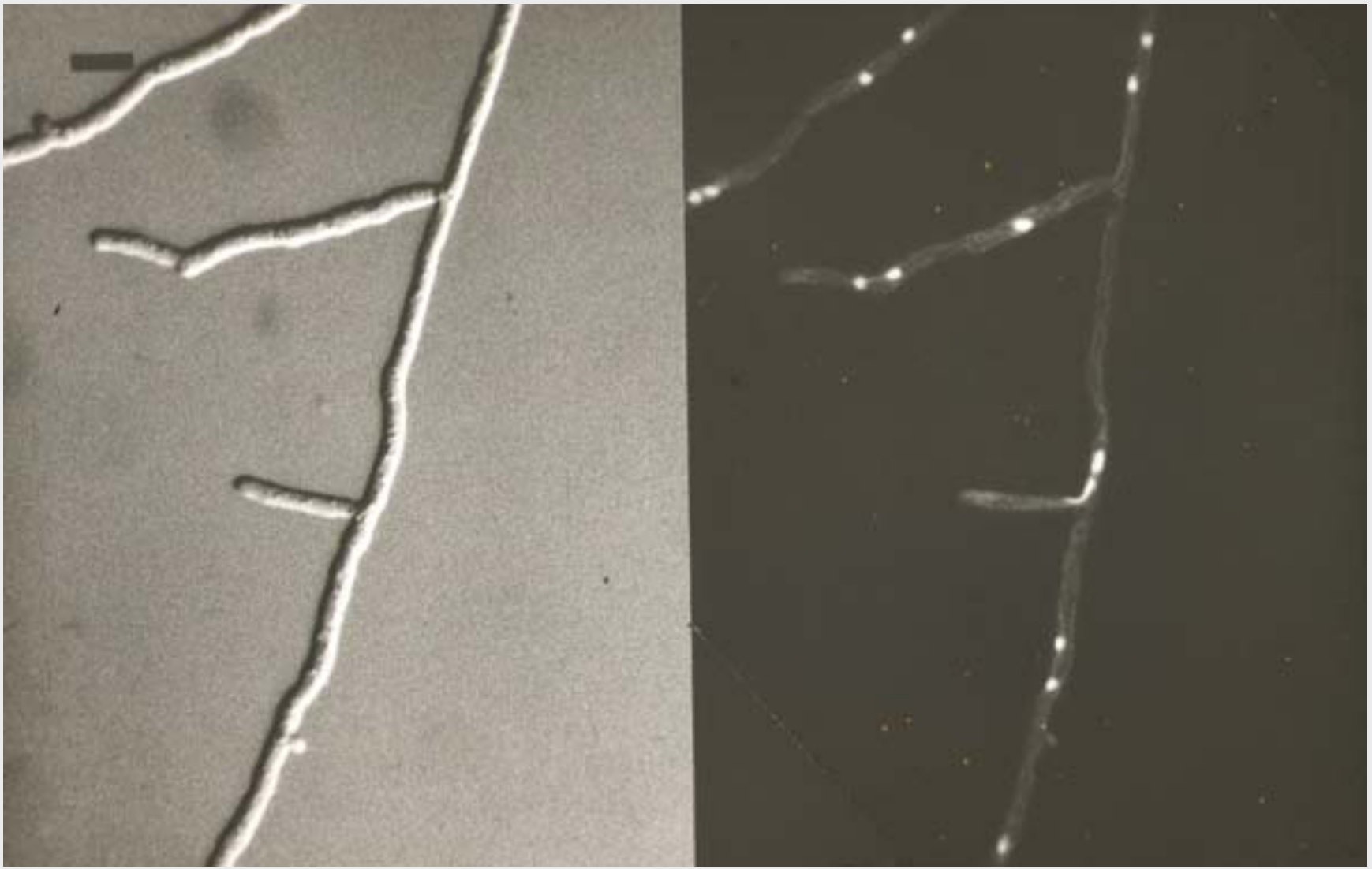
Mushrooms

Parasol Mushroom

Macrolepiota procera

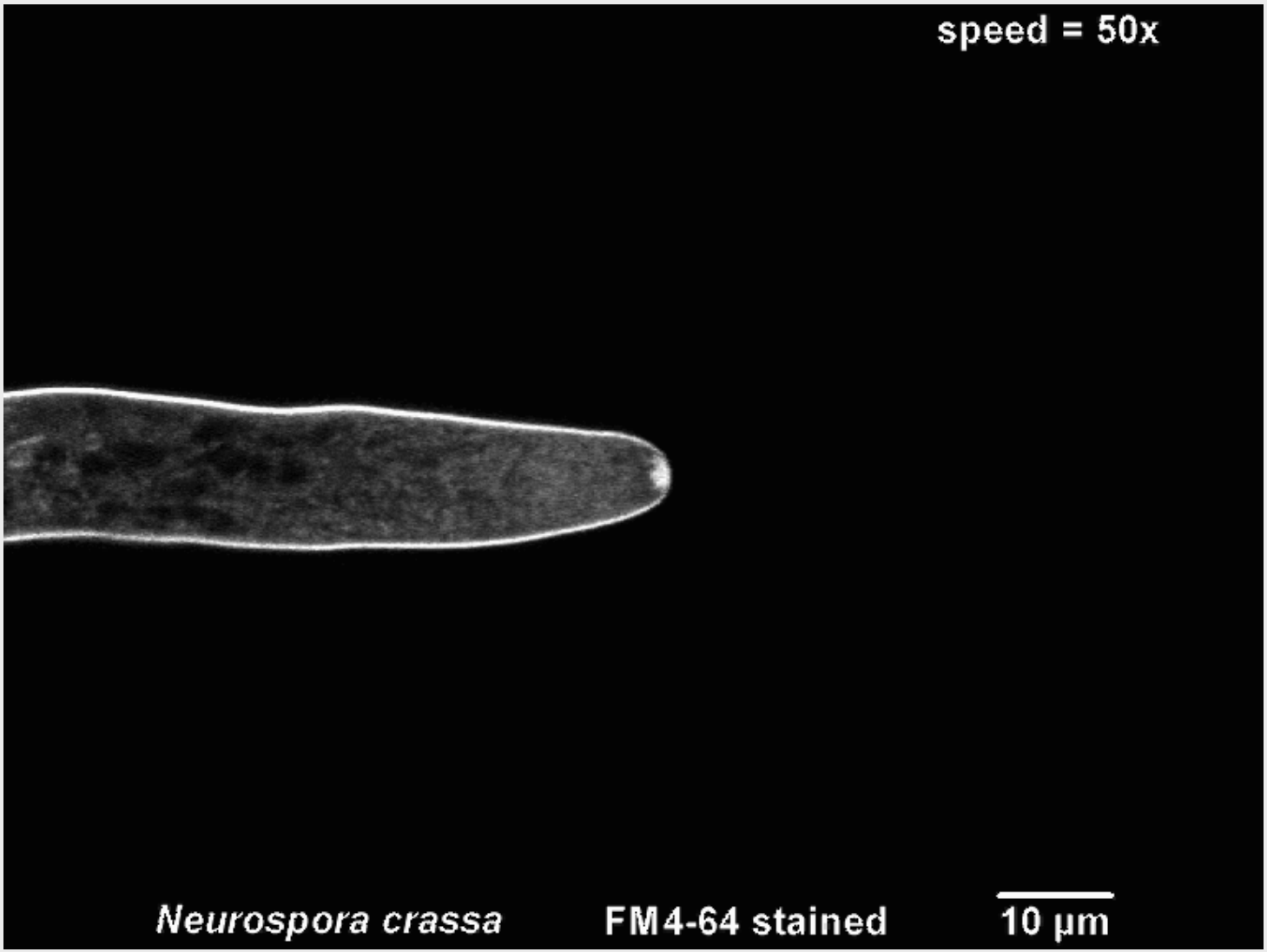


Three Parts of a Mushroom - C. T. Ingold

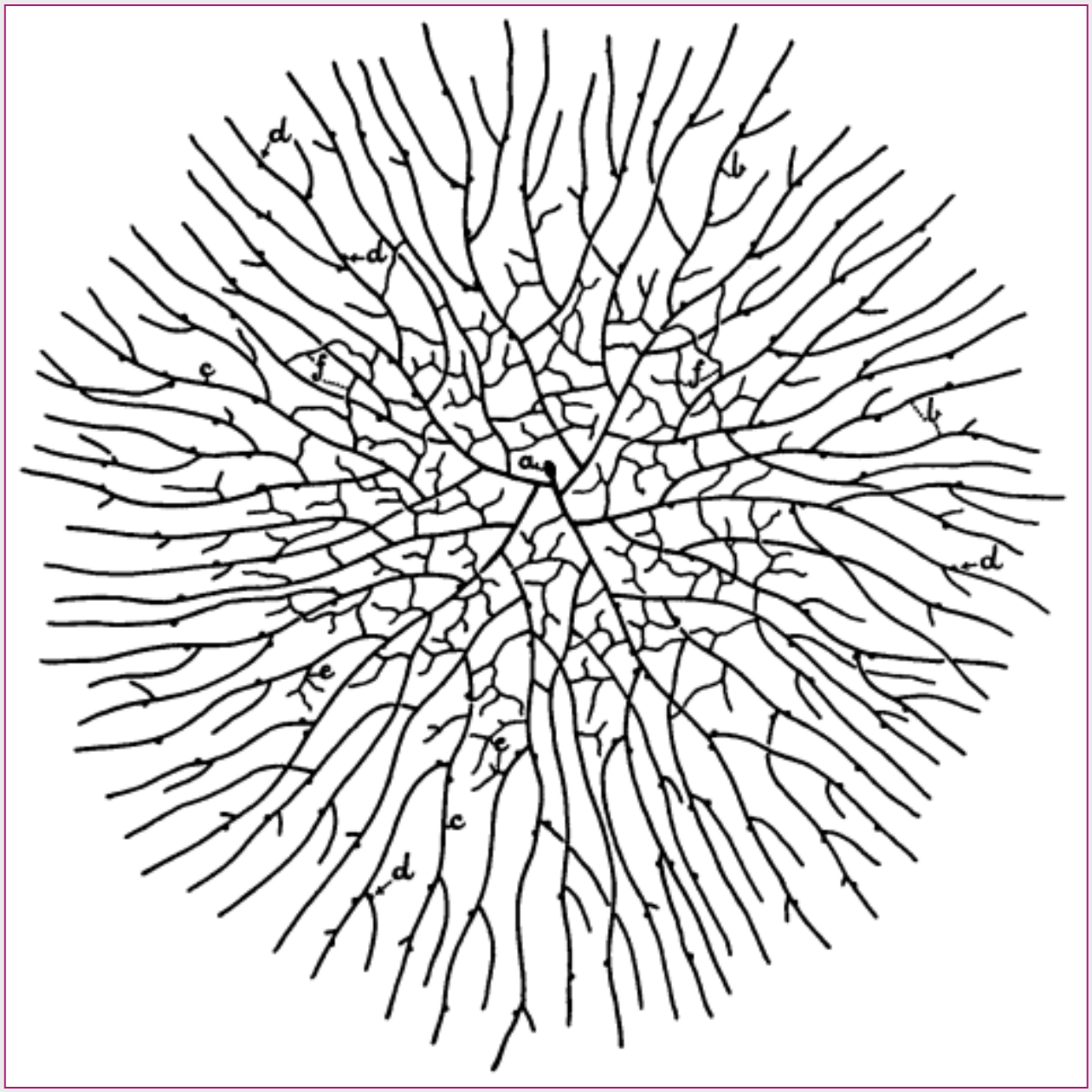


Hypha with nuclei, *Tulasnella* sp.

The Hypha



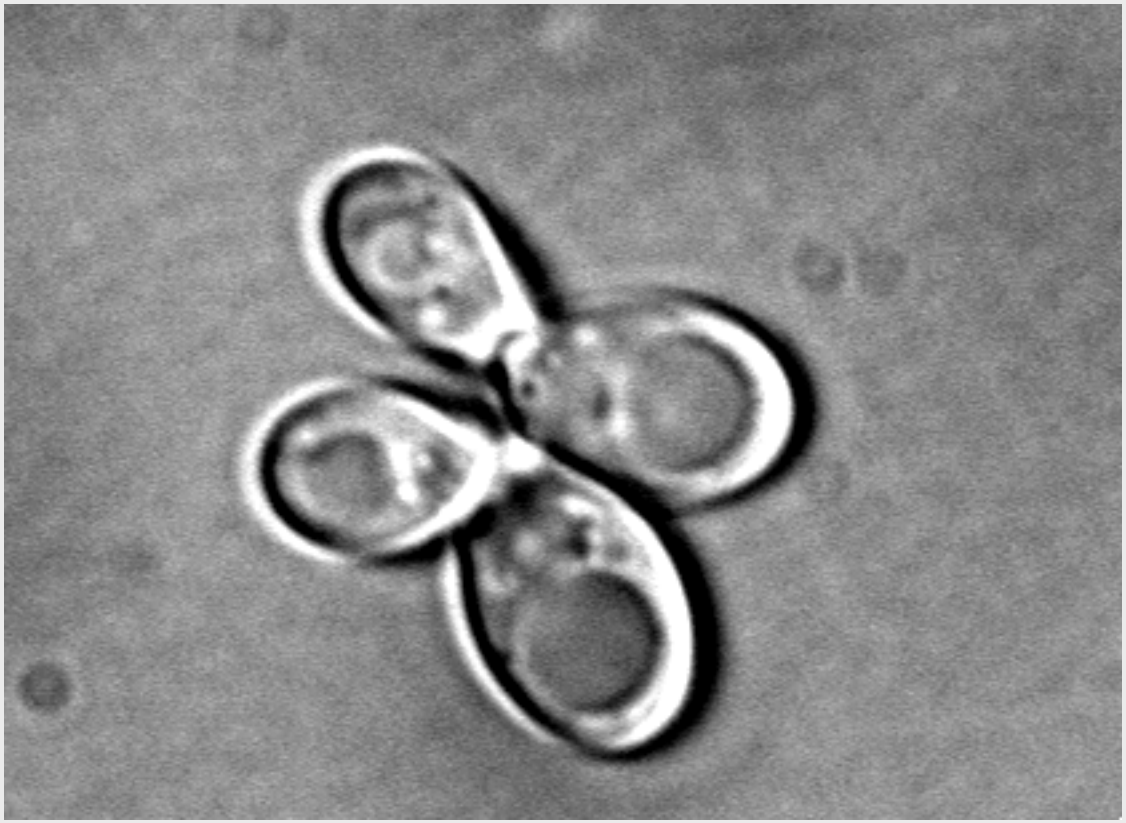
Jacobson, Hickey, Glass & Read



The Mycelium

A. H. R. Buller 1931

Yeast: growth and “spores” at the same time.



http://genome-www.stanford.edu/Saccharomyces/

Diane Nowicki and Ryan Liermann

Leavened Bread

http://en.wikipedia.org/wiki/Bread

Alcoholic Beverages

www.apartmenttherapy.com

Leavened Bread

http://en.wikipedia.org/wiki/Bread

Alcoholic Beverages

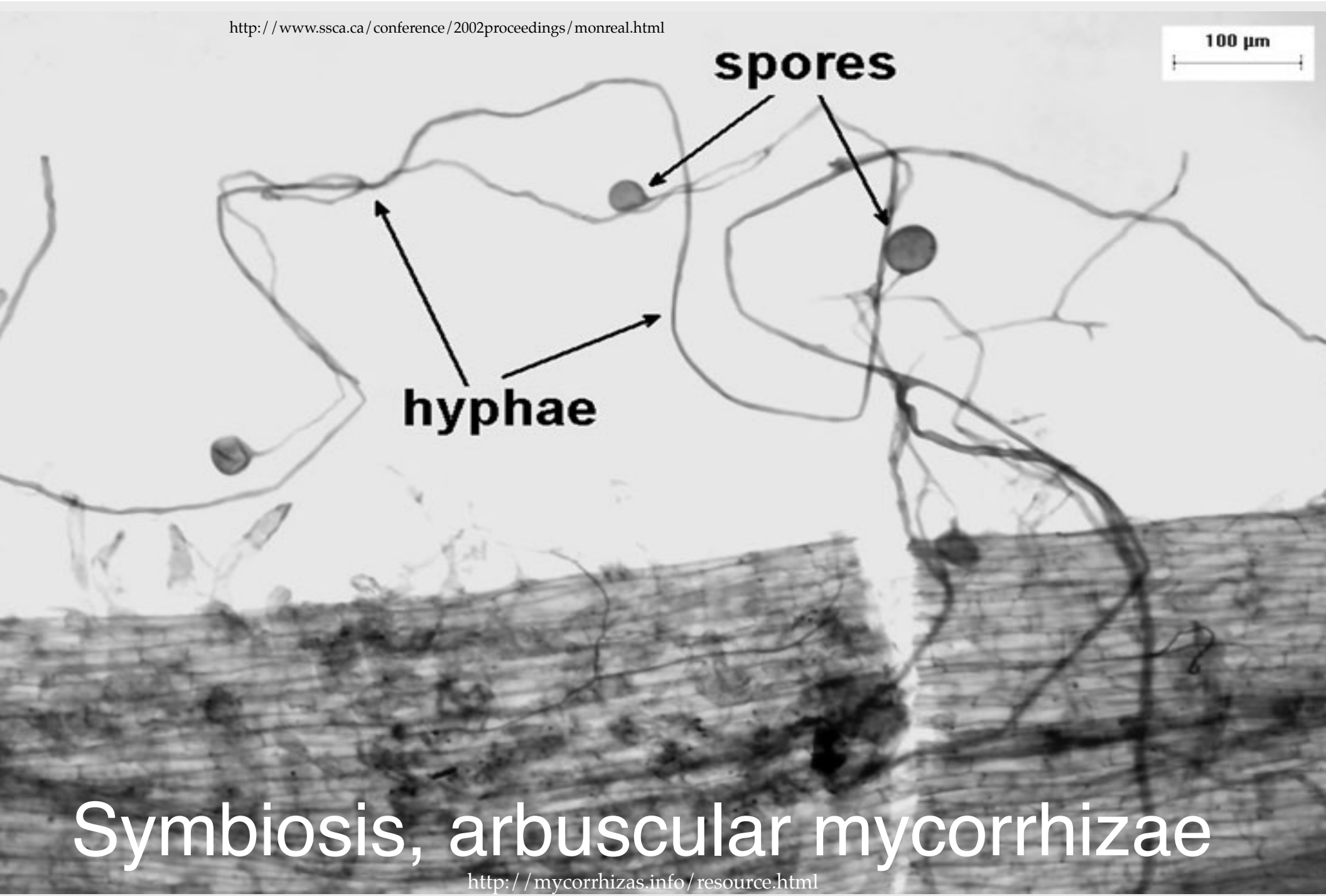
: perso.club-internet.fr

www.apartmenttherapy.com

Total Revenue for Selected Industries

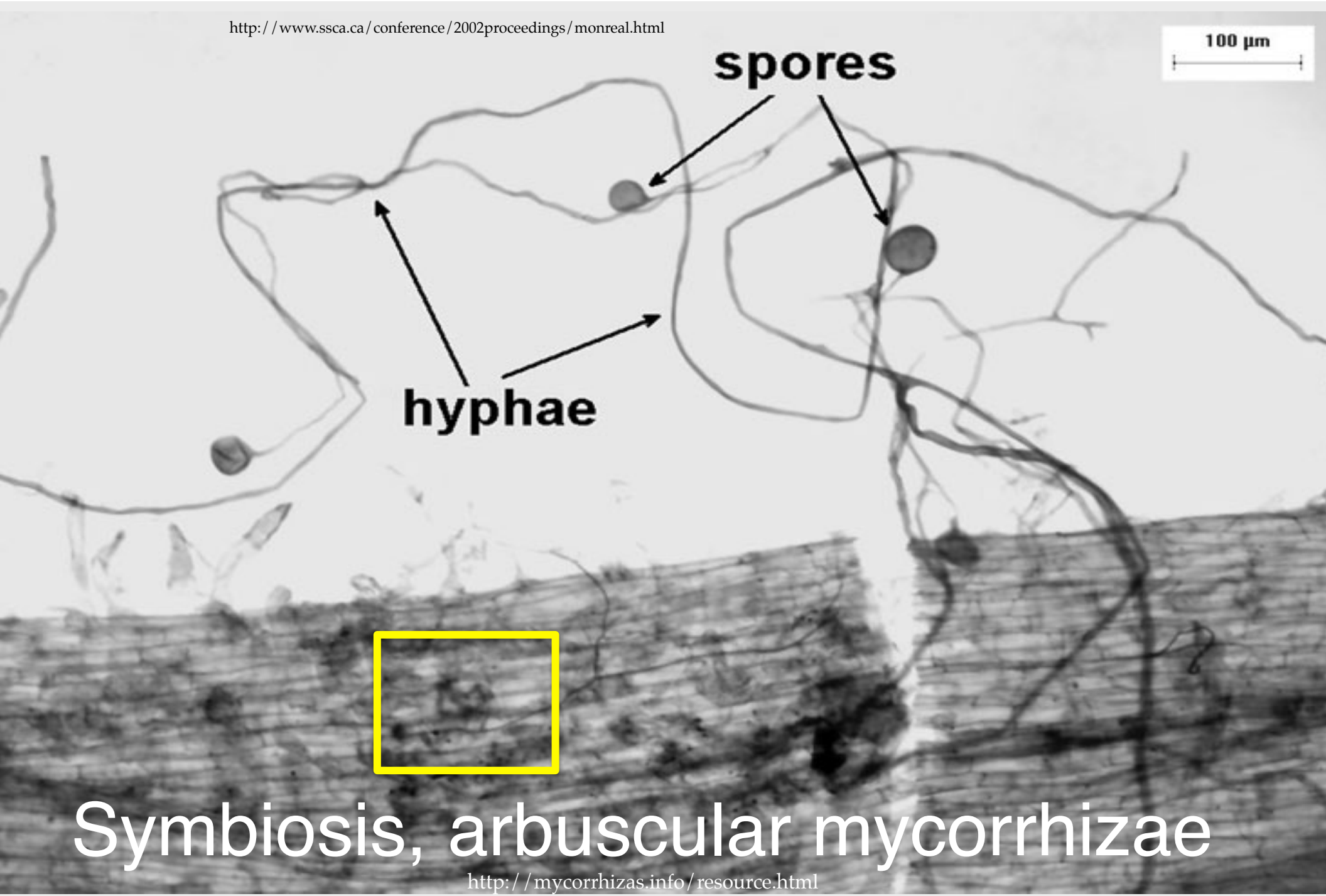
Alcoholic Beverages	$1000 Billion
Automotive	$900 Billion
Aerospace	$666 Billion
Crude oil	$1300 Billion

http://www.ssca.ca/conference/2002proceedings/monreal.html



Symbiosis, arbuscular mycorrhizae

http://mycorrhizas.info/resource.html



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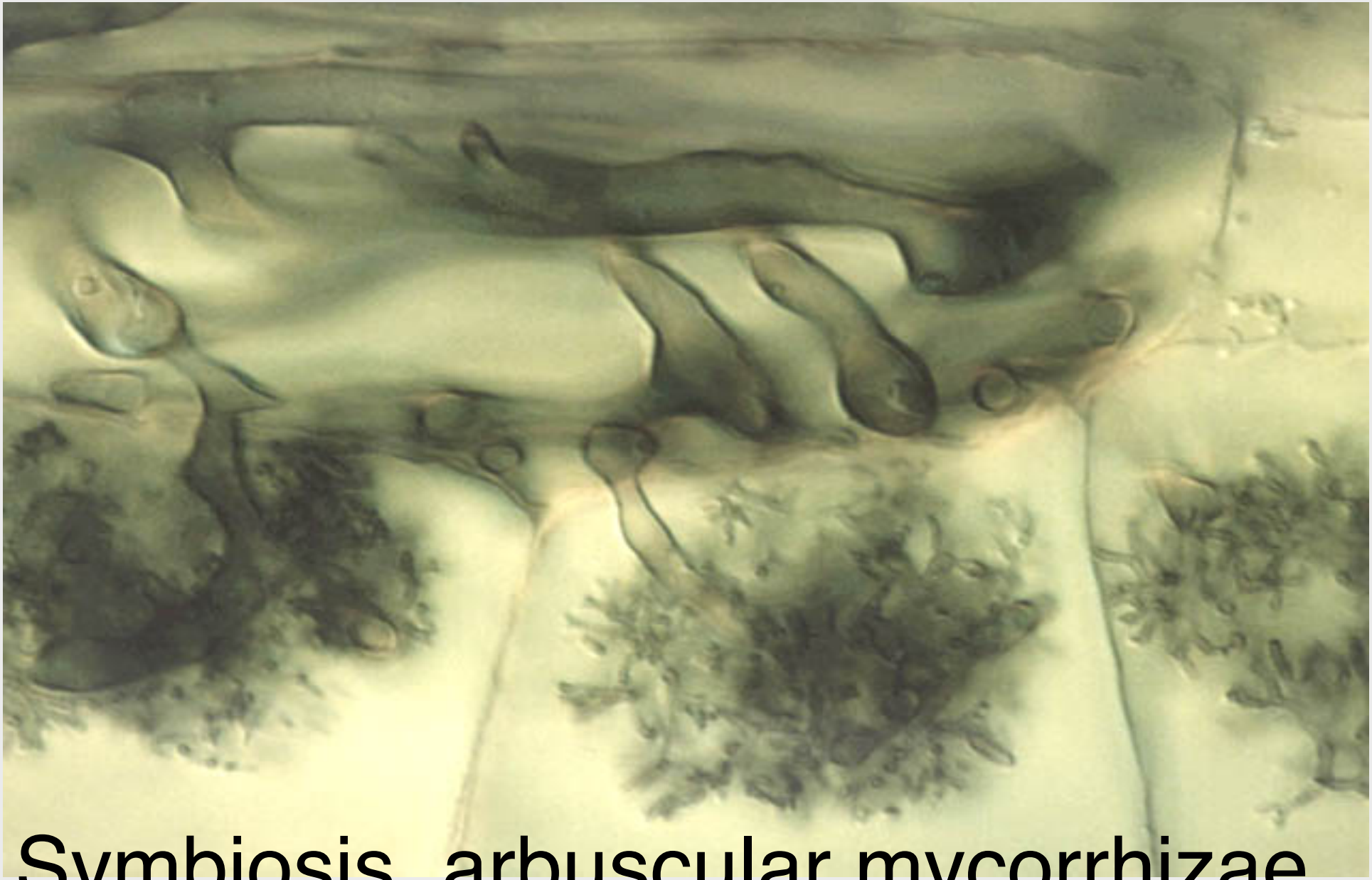

Symbiosis, arbuscular mycorrhizae

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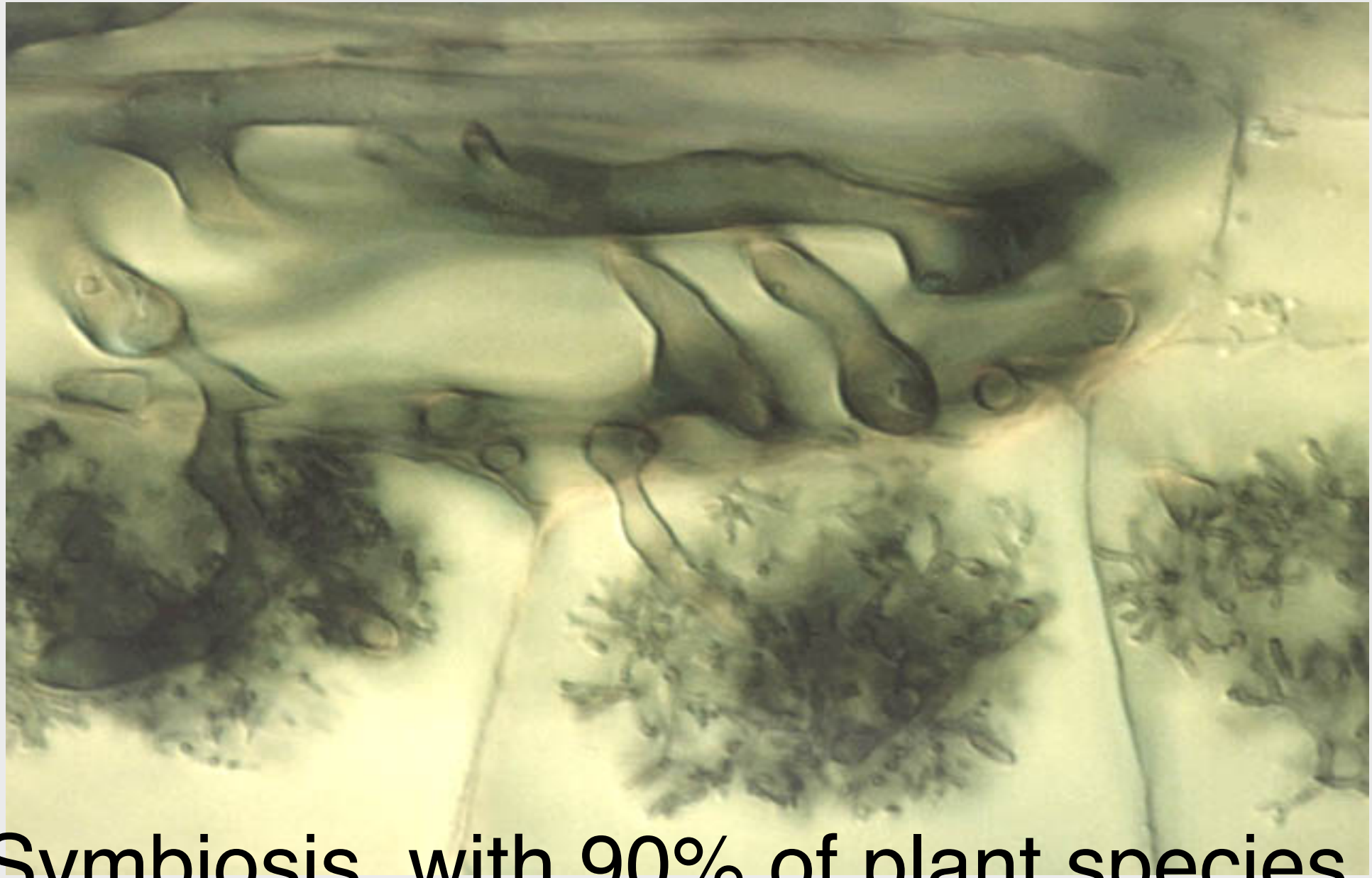
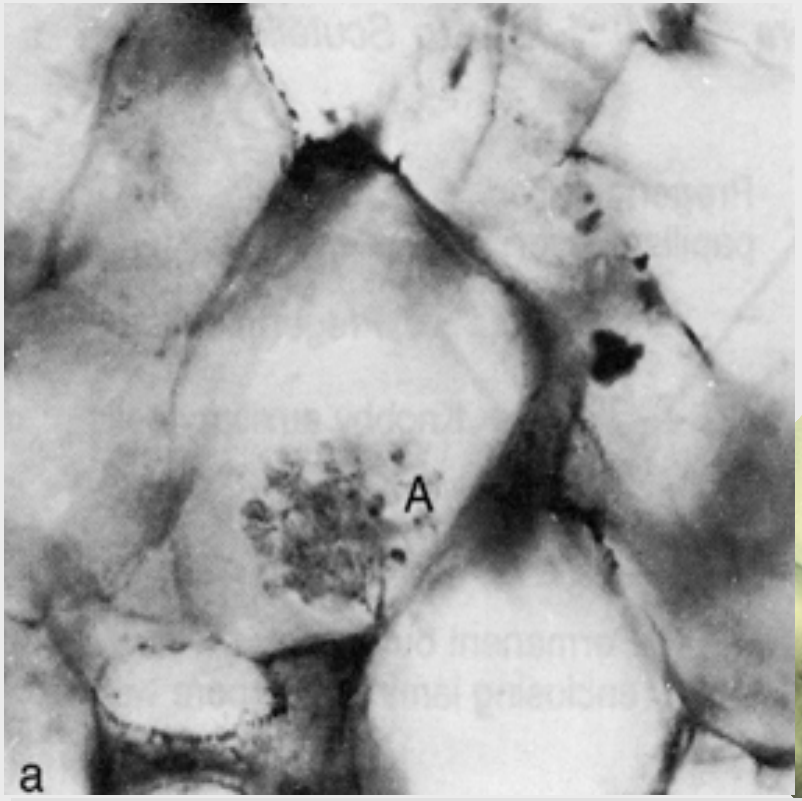
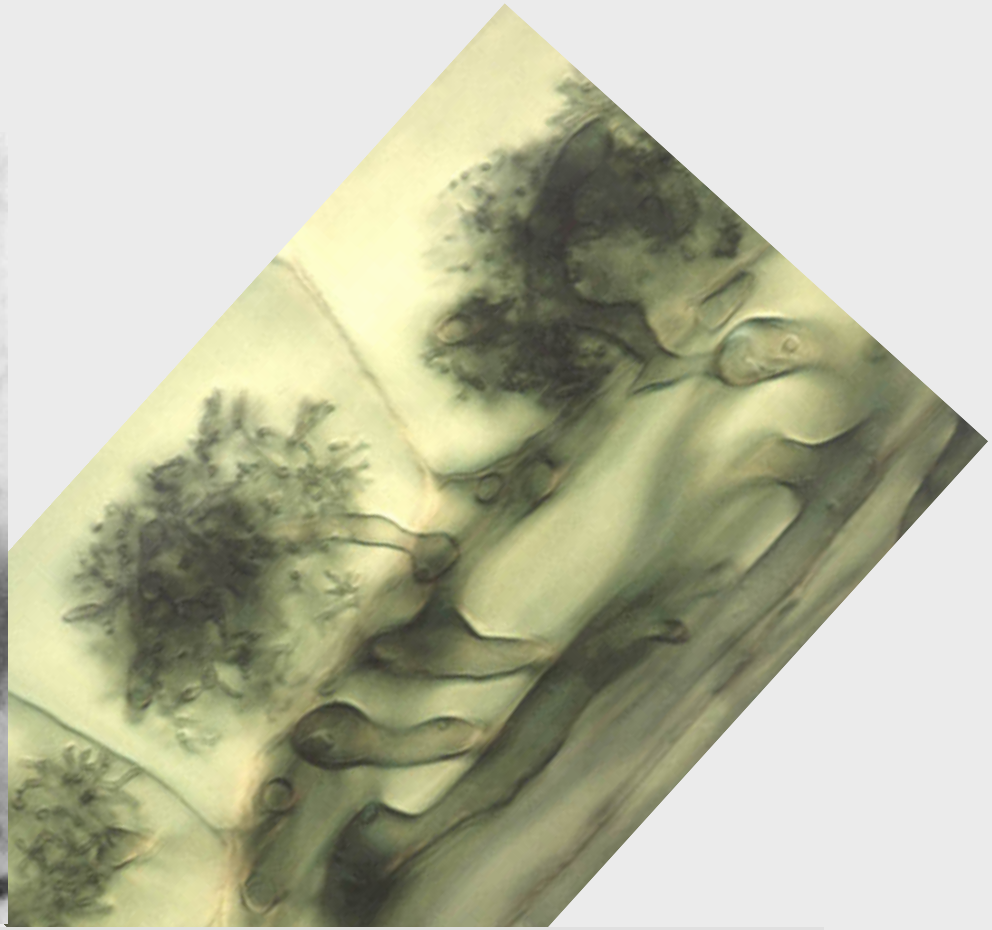


Symbiosis, with 90% of plant species

http://mycorrhizas.info/resource.html





Devonian Fossil
400 mya

Modern Glomales

Remy, Taylor et al. 1994

Symbiosis, Ectomycorrhizae

Antonio Izzo - Tom Bruns

Symbiosis, with Oaks and Pines

Antonio Izzo - Tom Bruns

Batrachochytrium & Sierran yellow-legged frog.

Photos from Vance Vreedenberg and Jess Morgan

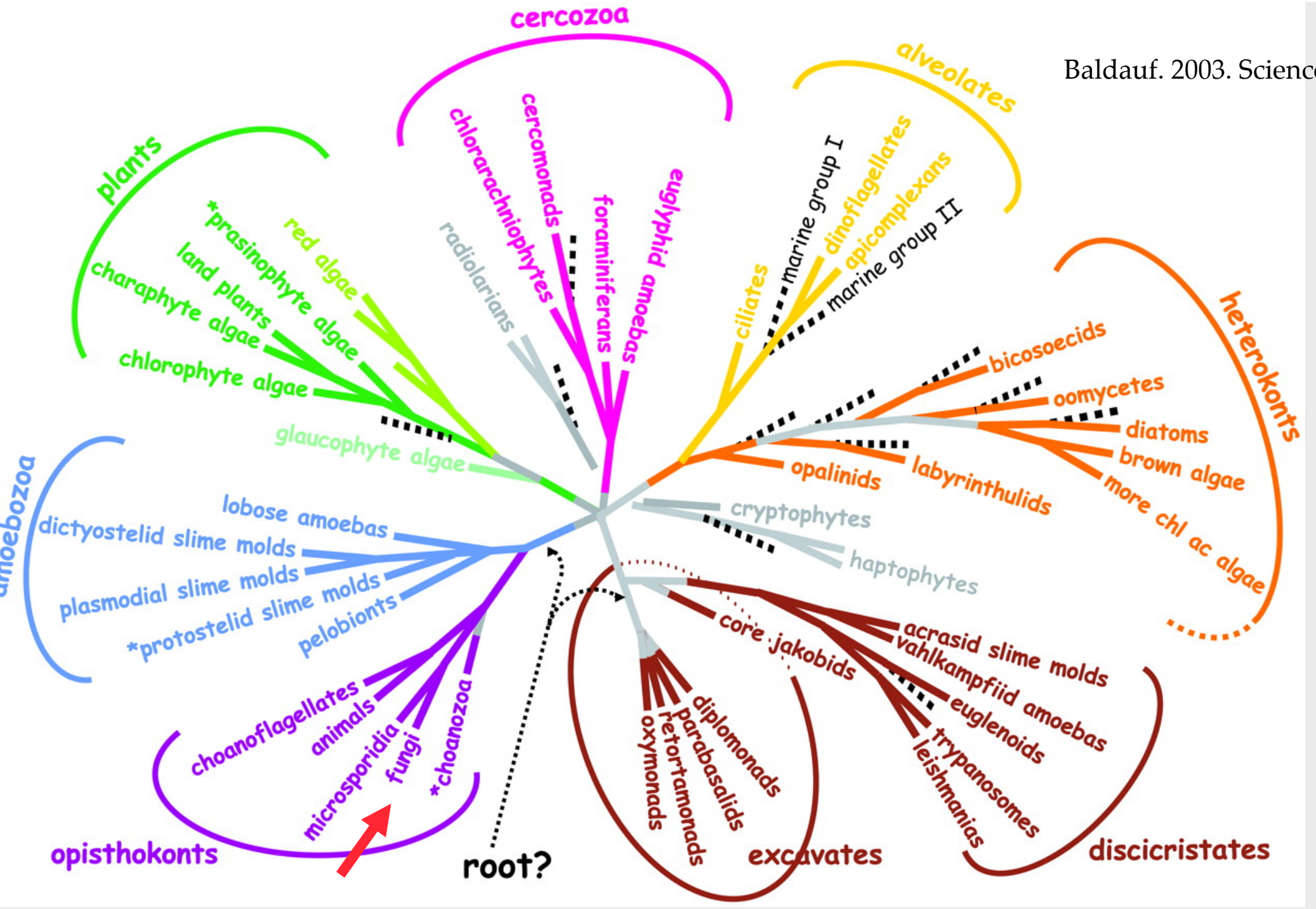
. . . and another 30% of amphibians.

Photos from Vance Vreedenberg and Jess Morgan

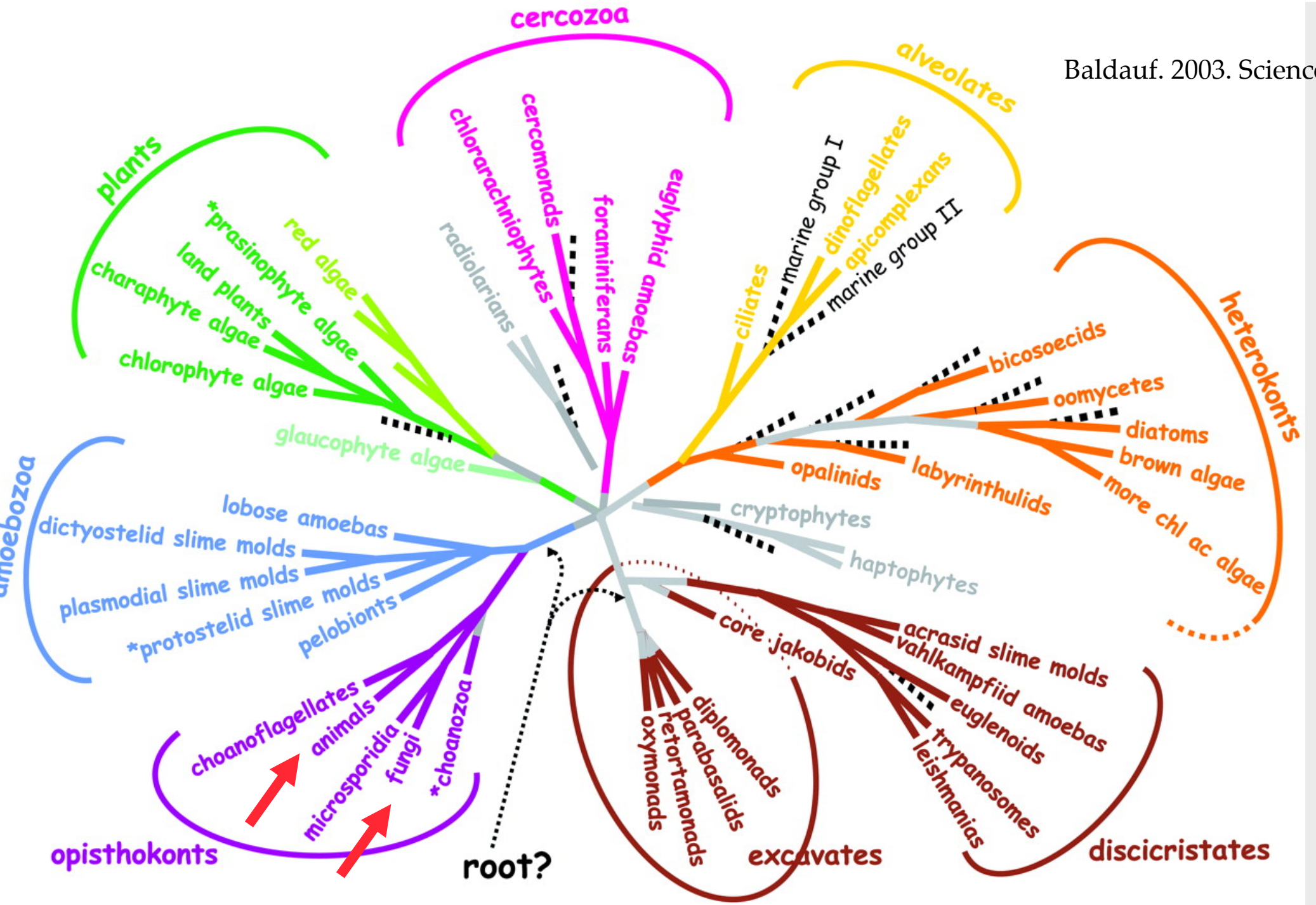
What are Fungi?

Where are Fungi in the Tree of Life?

Adaptation.



Baldauf. 2003. Science



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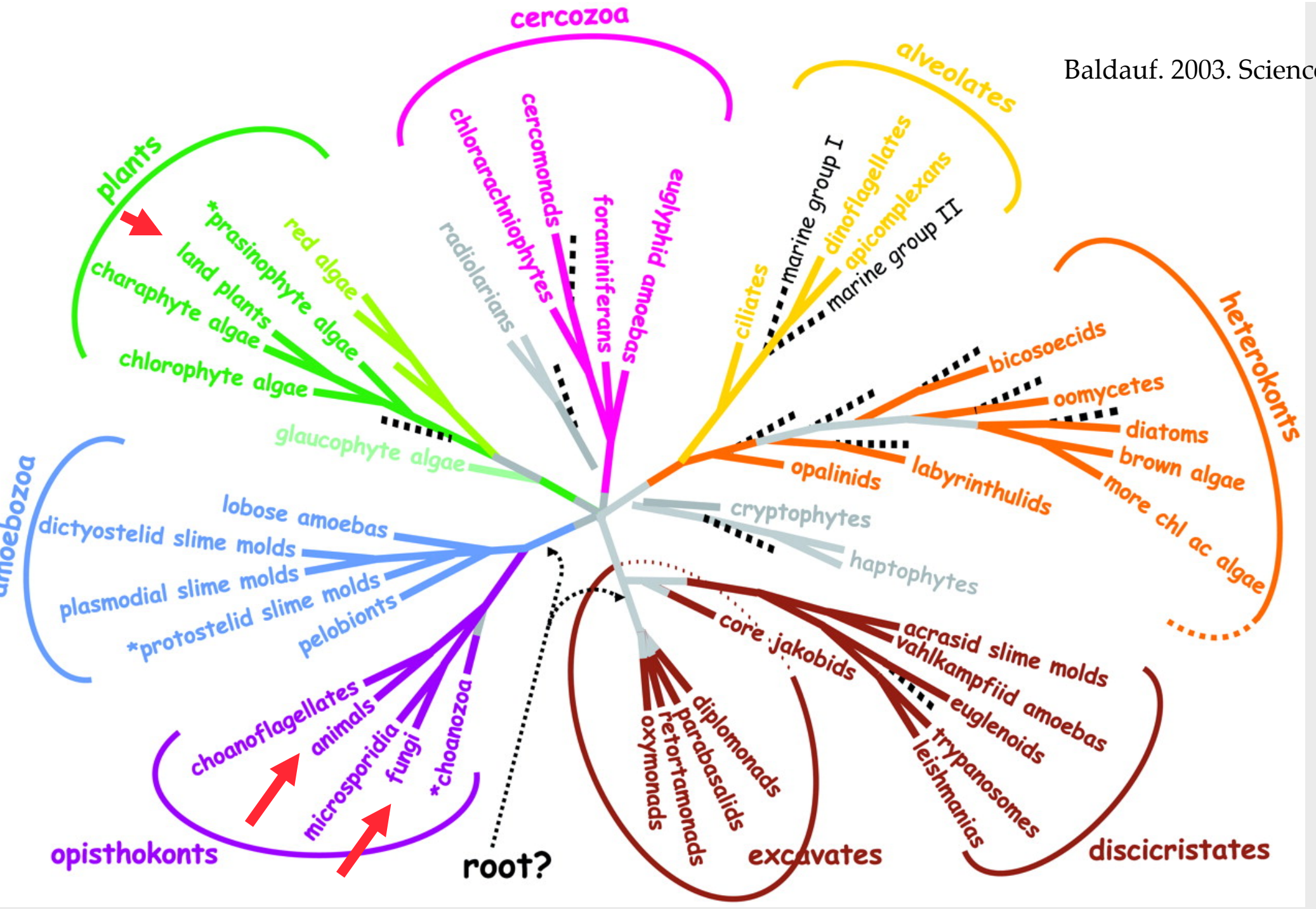

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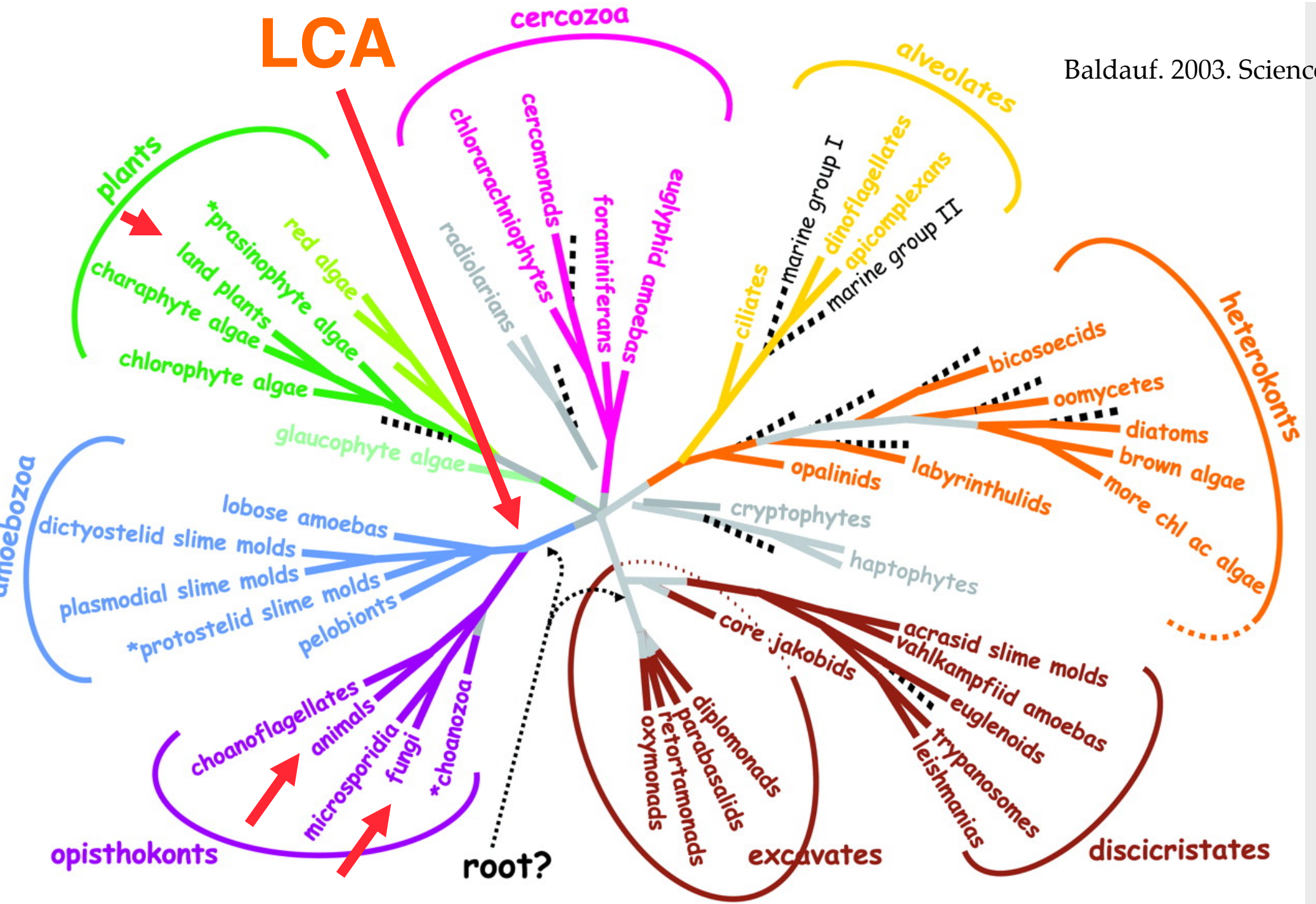
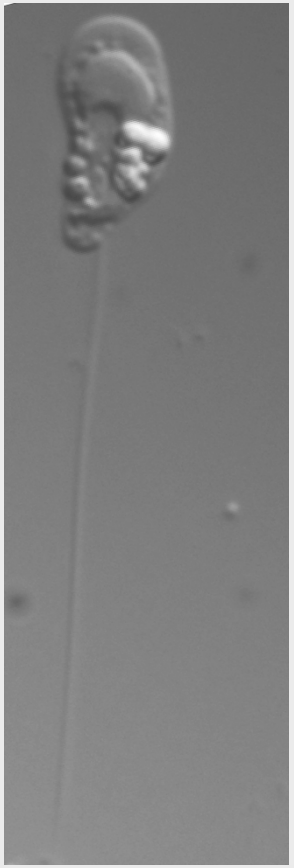


Baldauf. 2003. Science

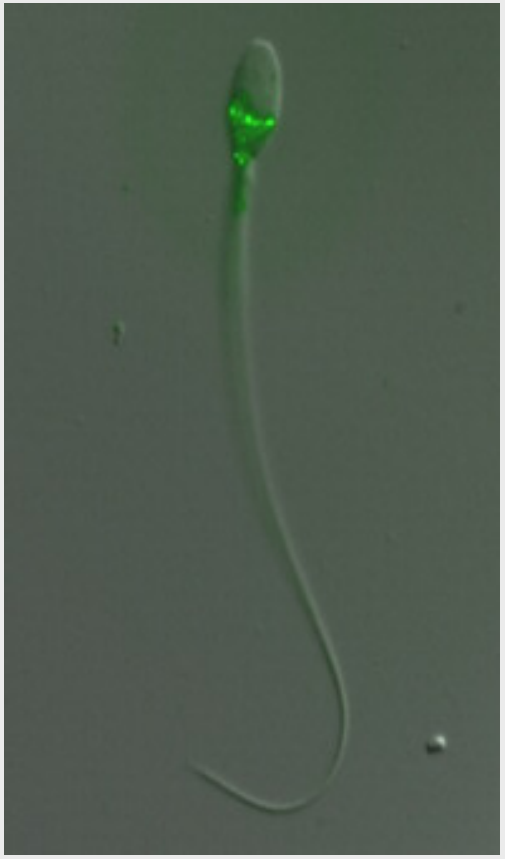
LAST COMMON ANCESTOR - FUNGI & ANIMALS



Fungal Zoospore

Blastocladiella simplex

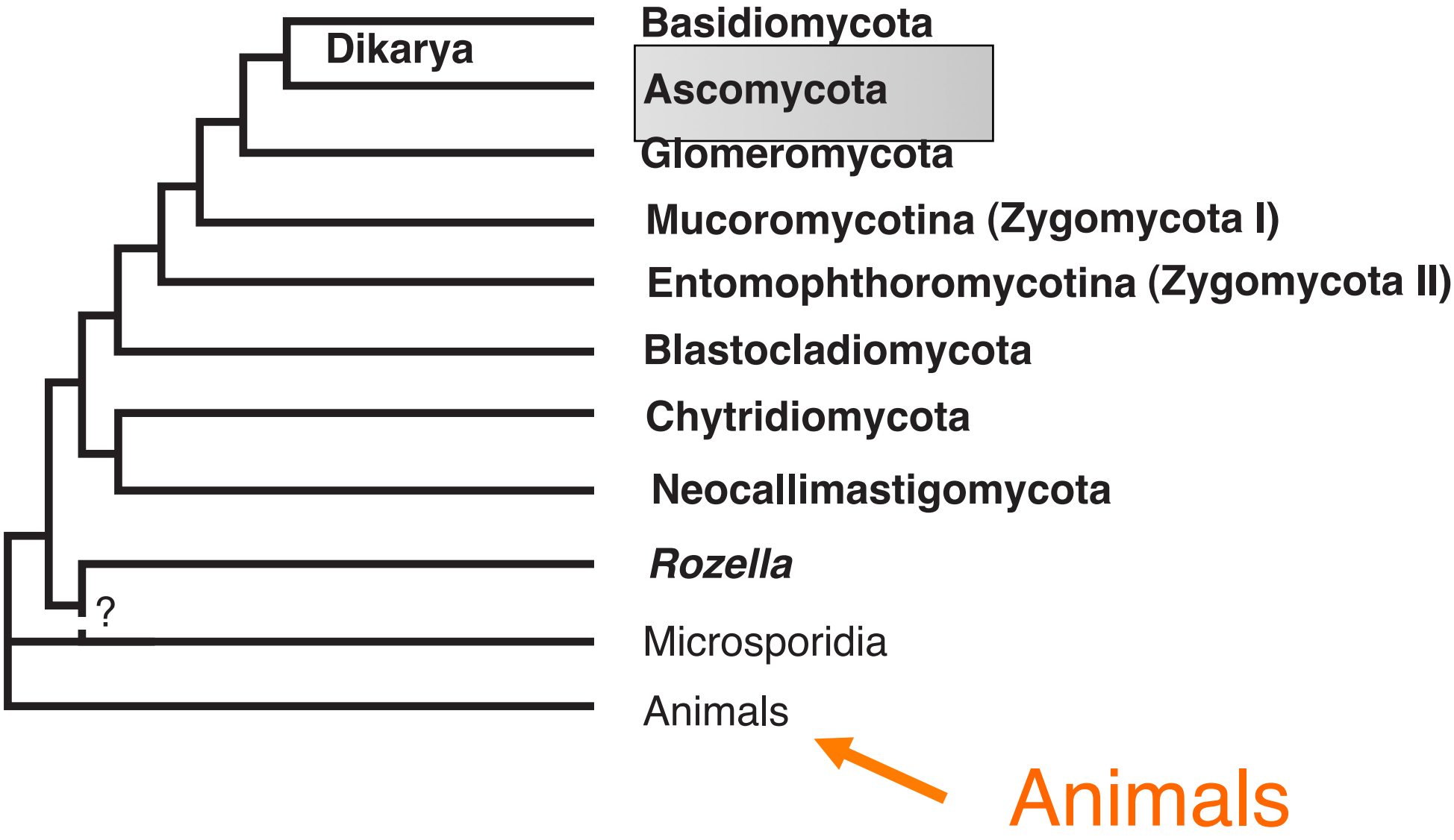
Stajich et al. 2008 Current Biology

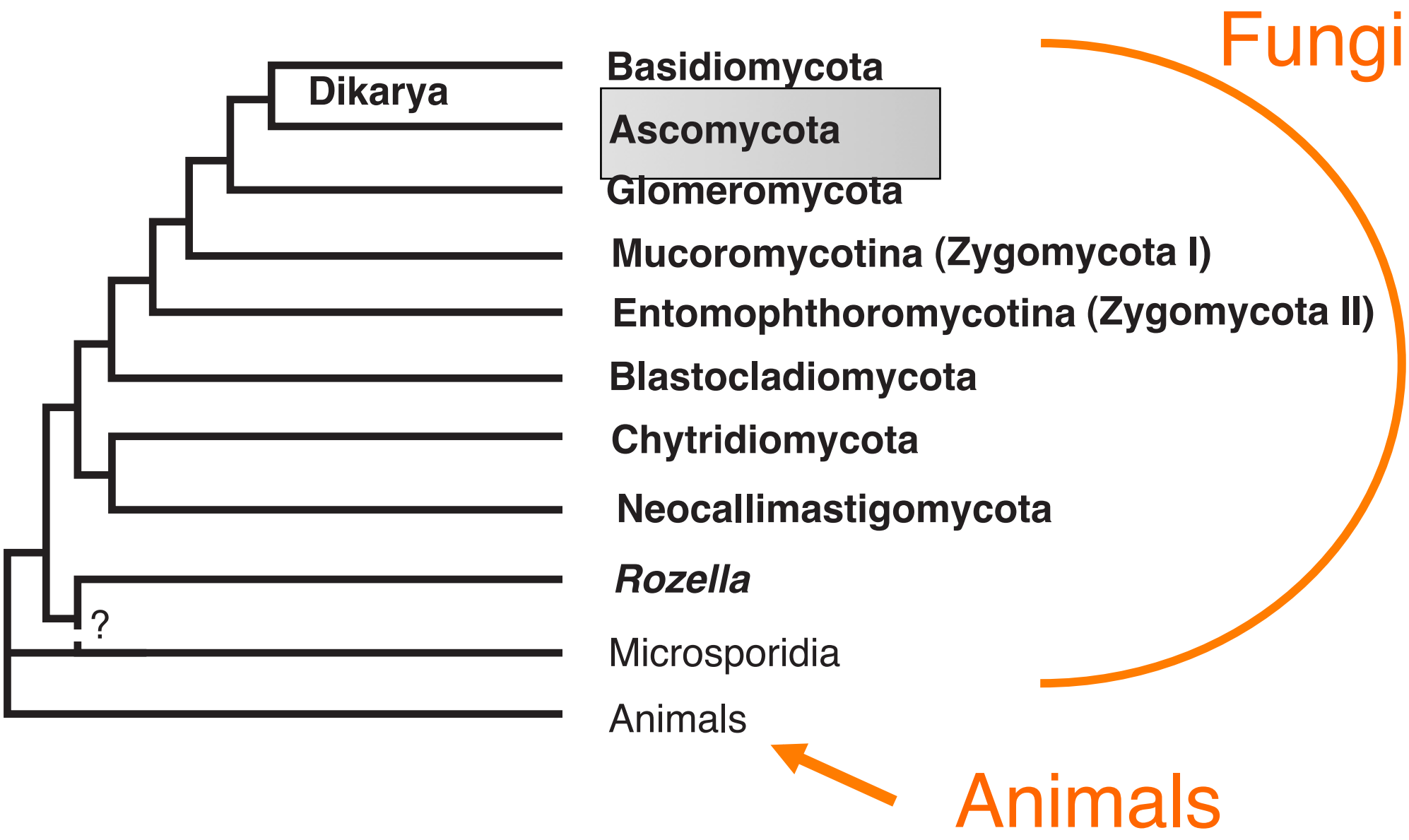


Mammalian Spermatozooan

Equus ferus caballus

Wrench et al. 2010. Animal Repro Sci


Dikarya
Basidiomycota
Ascomycota
Glomeromycota
Mucoromycotina (Zygomycota I)
Entomophthoromycotina (Zygomycota II)
Blastocladiomycota
Chytridiomycota
Neocallimastigomycota
Rozella
?
Microsporidia
Animals
Animals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Blastocladiomycota
Chytridiomycota
Neocallimastigomycota
Rozella
?
Microsporidia
Animals
Fungi
Animals

Neurospora

Sordariales, *Neurospora*

One gene - one enzyme

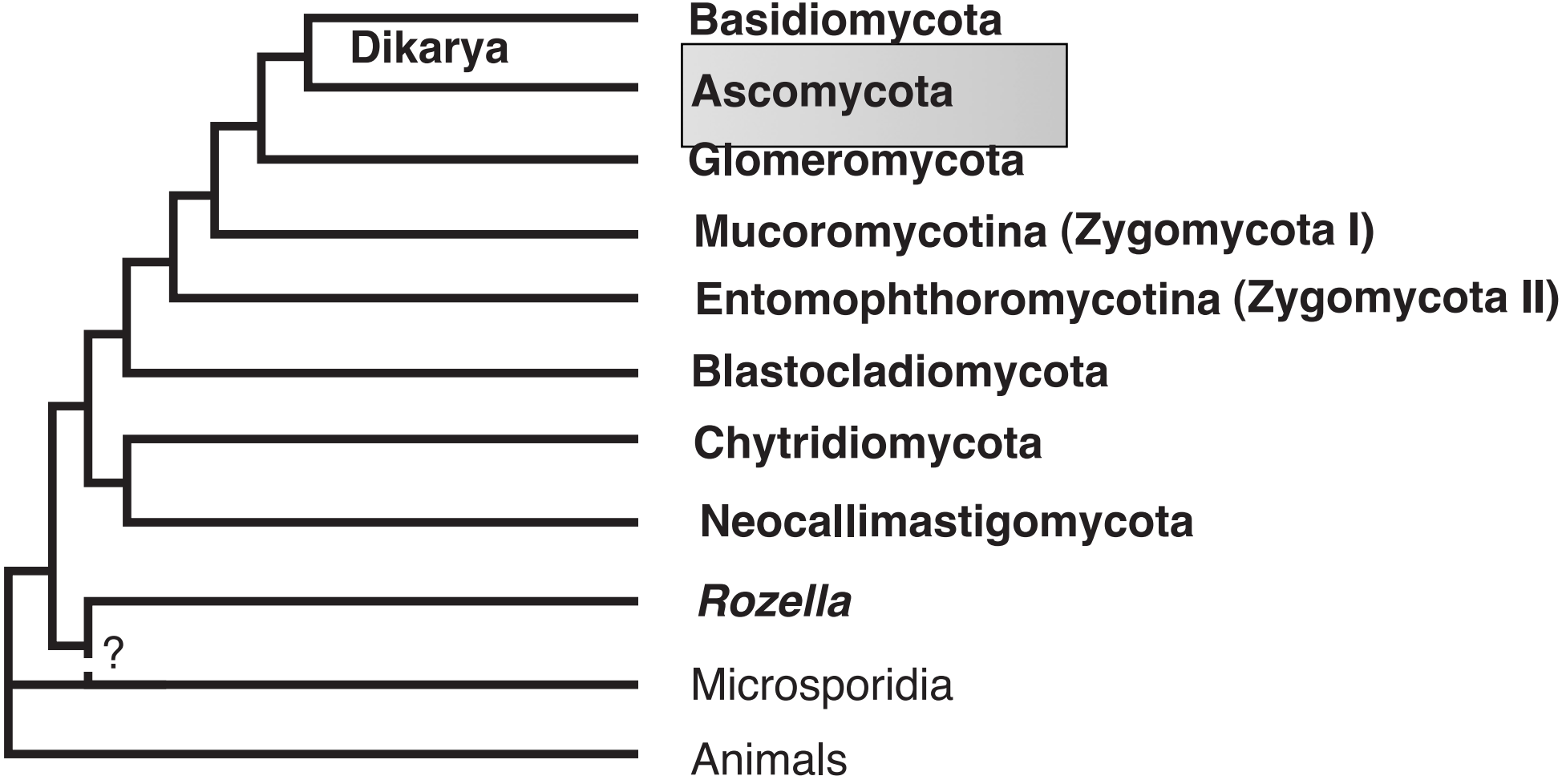
Nobel Prize in Physiology or Medicine, 1958

Beadle Tatum Lederberg

What are Fungi?

Where are Fungi in the Tree of Life?

Adaptation.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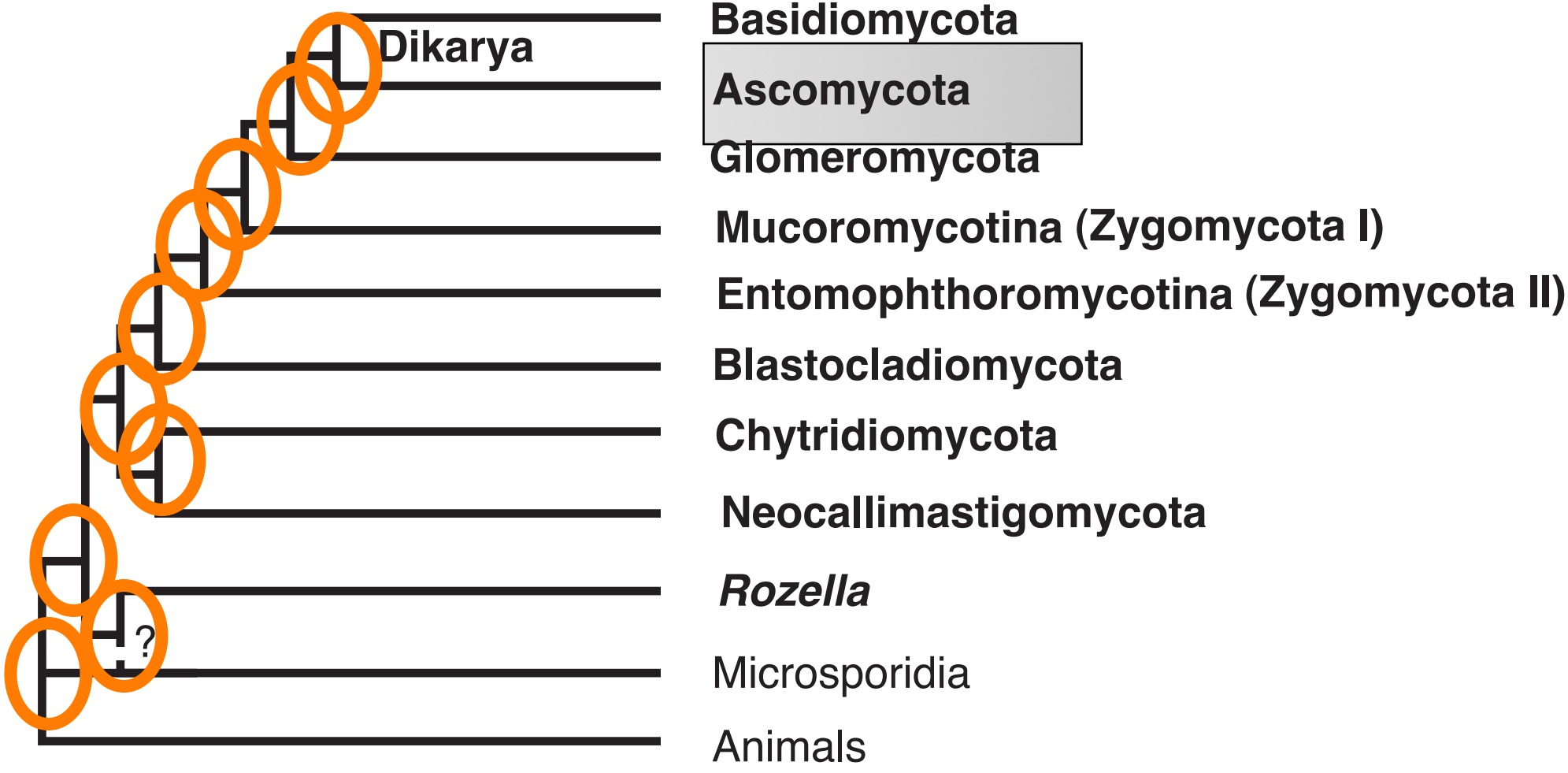
Microsporidia
Animals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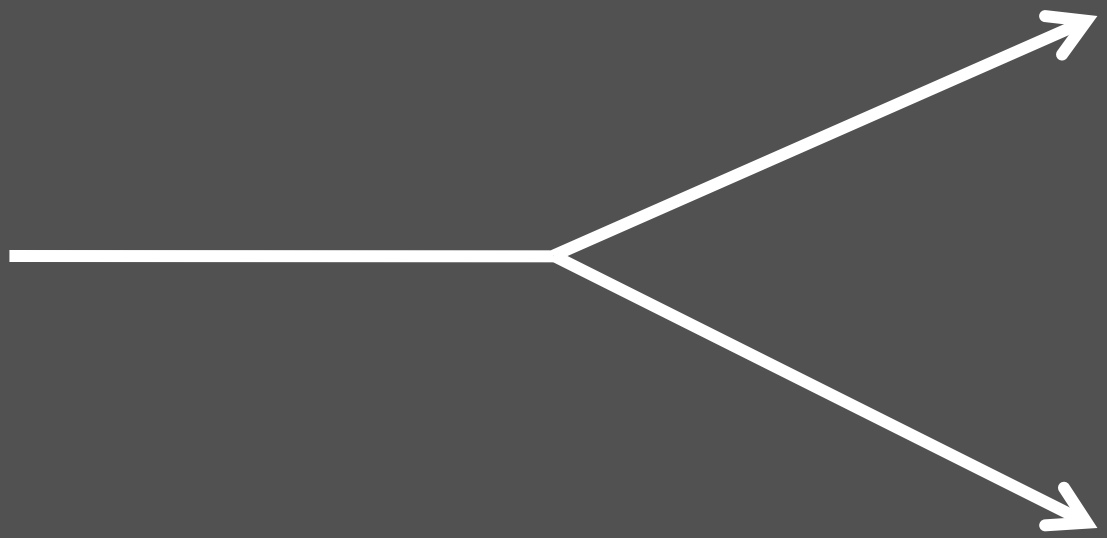
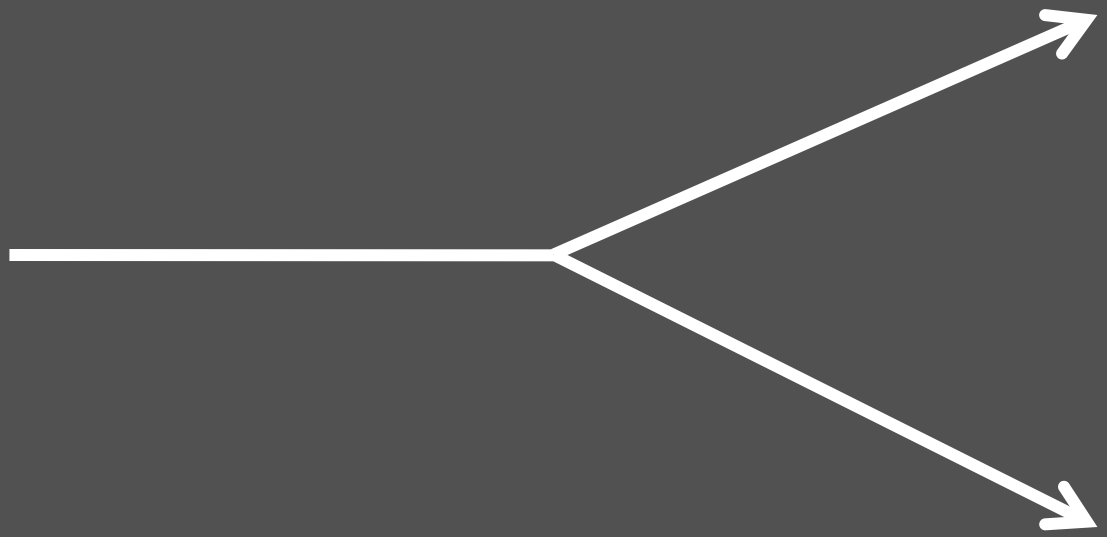
Rozella
Microsporidia
Animals

Divergence



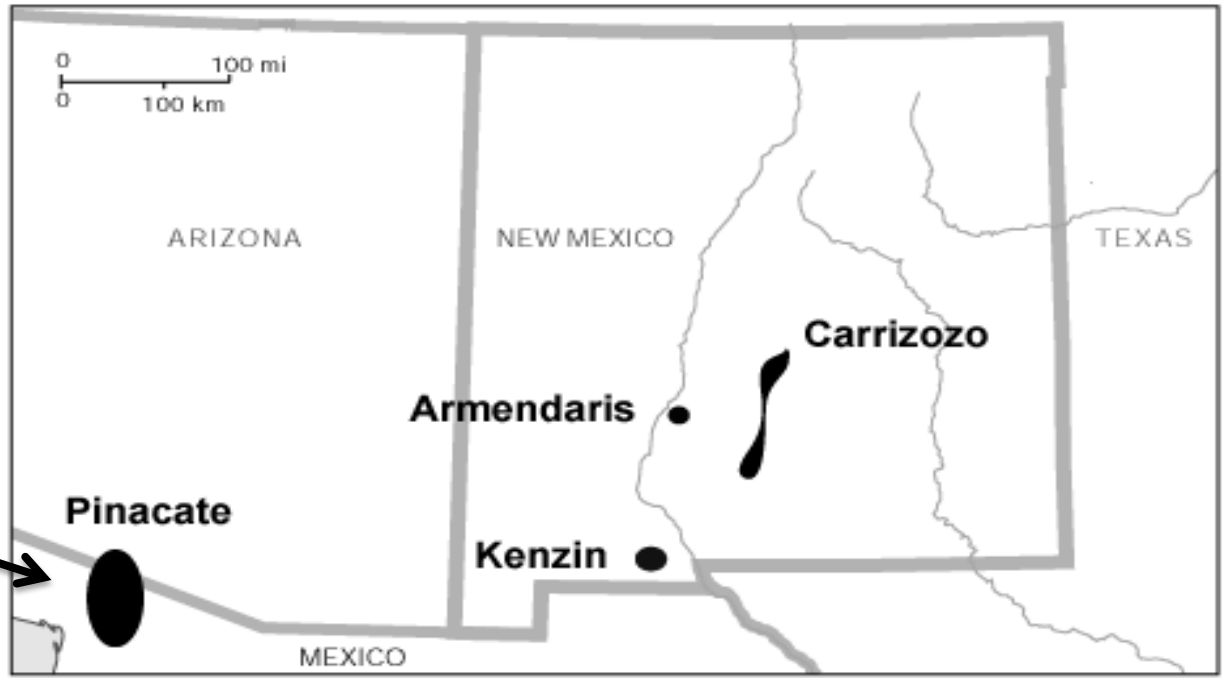
Divergence

Adaptation

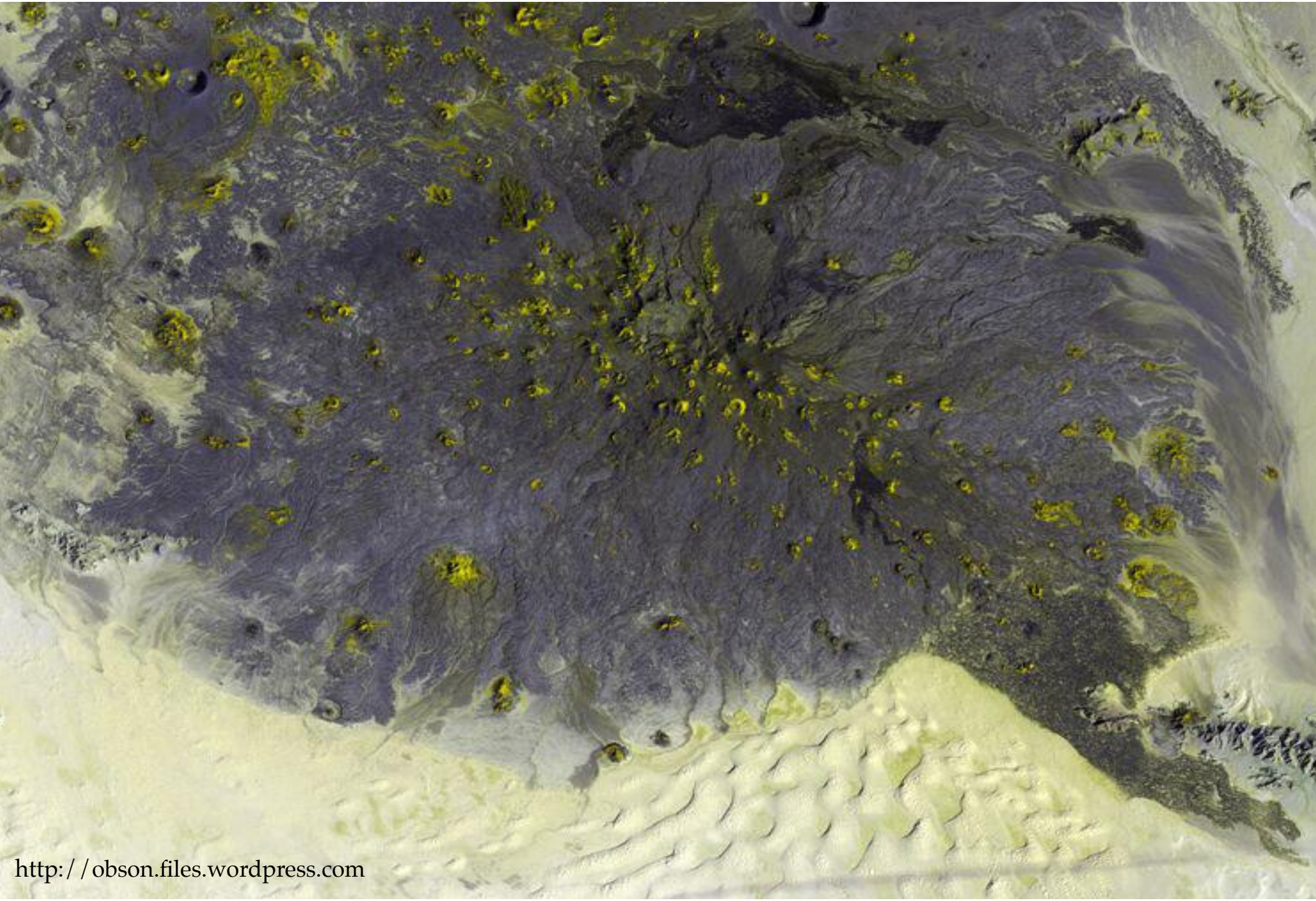


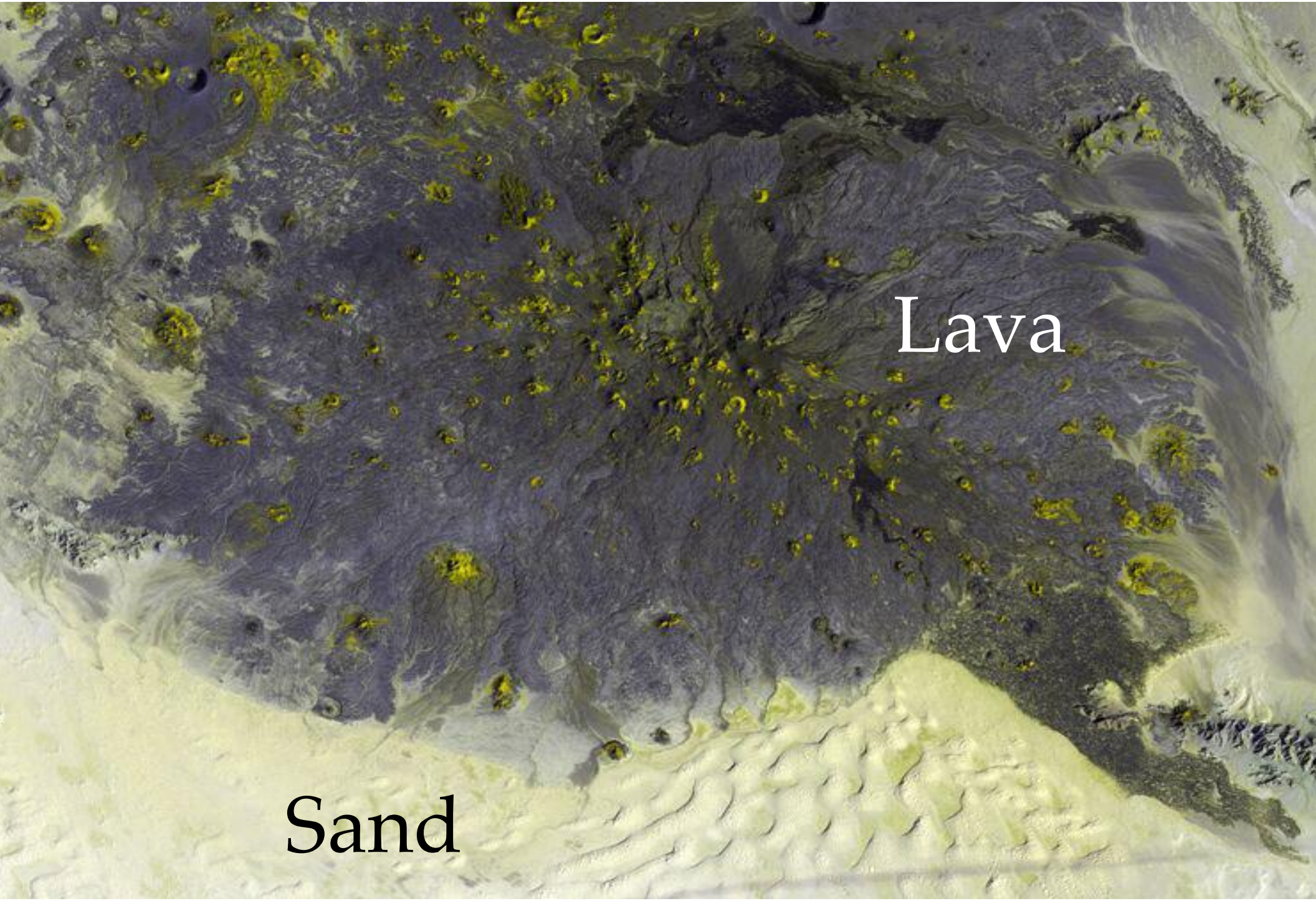
Adaptation:
What environmental factors?
What adaptive phenotypes?

Lava flows



Hopi E. Hoekstra and Michael W. Nachman. 2005. UC Press


http://obson.files.wordpress.com


Lava
Sand

Adaptive Coat Color

Chaetodipus intermedius

Feder, ME and T Mitchell-Olds. 2003. Nature Reviews Genetics

Nature Reviews | Genetics

Feder, ME and T Mitchell-Olds. 2003. Nature Reviews Genetics

What environmental factor?
What phenotype?

GWA

GWA

GWA Girls with Attitude
GWA Gender and Water Alliance
GWA Georgia Watermelon Association
GWA Google Web Accelerator
GWA Garden Writers Association
GWA General Weighted Average
GWA Genome Wide Association
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GWA Game Winning Assist (futbol)

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nature

Article

Nature **445**, 881-885 (22 February 2007) | doi:10.1038/nature05616; Received 11 November 2006; Accepted 23 January 2007; Published online 11 February 2007

A genome-wide association study identifies novel risk loci for type 2 diabetes

Robert Sladek[1,2,4], Ghislain Rocheleau[1,15], Johan Rung[4,15], Christian Dina[5,15], Lishuang Shen[1], David Serre[1], Philippe Boutin[5], Daniel Vincent[4], Alexandre Belisle[4], Samy Hadjadj[6], Beverley Balkau[7], Barbara Heude[7], Guillaume Charpentier[8], Thomas J. Hudson[4,9], Alexandre Montpetit[4], Alexey V. Pshezhetsky[10], Marc Prentki[10,11], Barry I. Posner[2,12], David J. Balding[13], David Meyre[5], Constantin Polychronakos[1,3] and Philippe Froguel[5,14]

nature

1,363 Individuals
3.3 billion nucleotides
392,935 vary

Article

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nature

1,363 Individuals
392,935 SNPs
1 in every 8500 nucleotides

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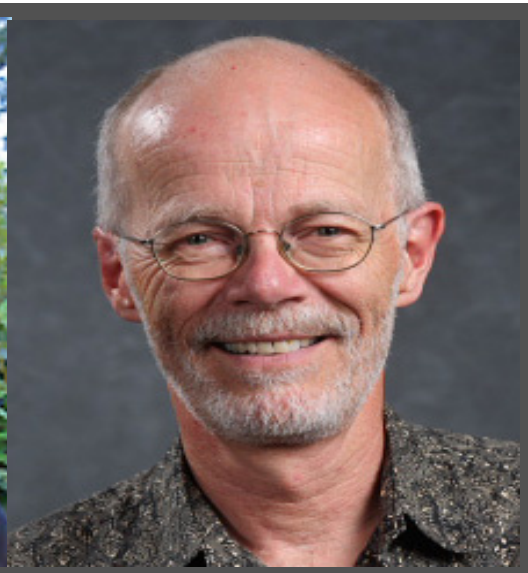
Louise Glass

Rachel Brem



John Taylor

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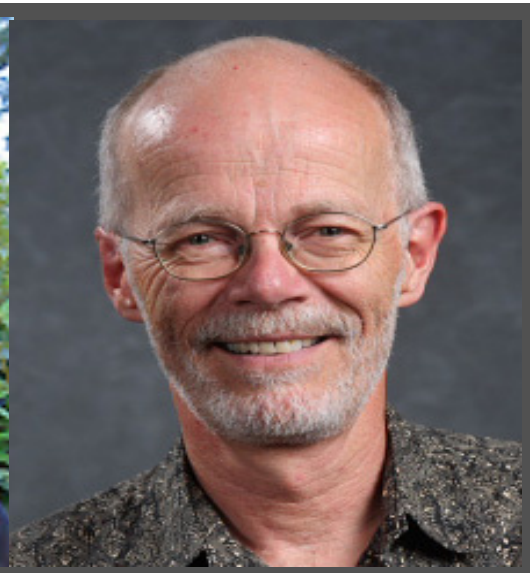


John Taylor

Charles Hall

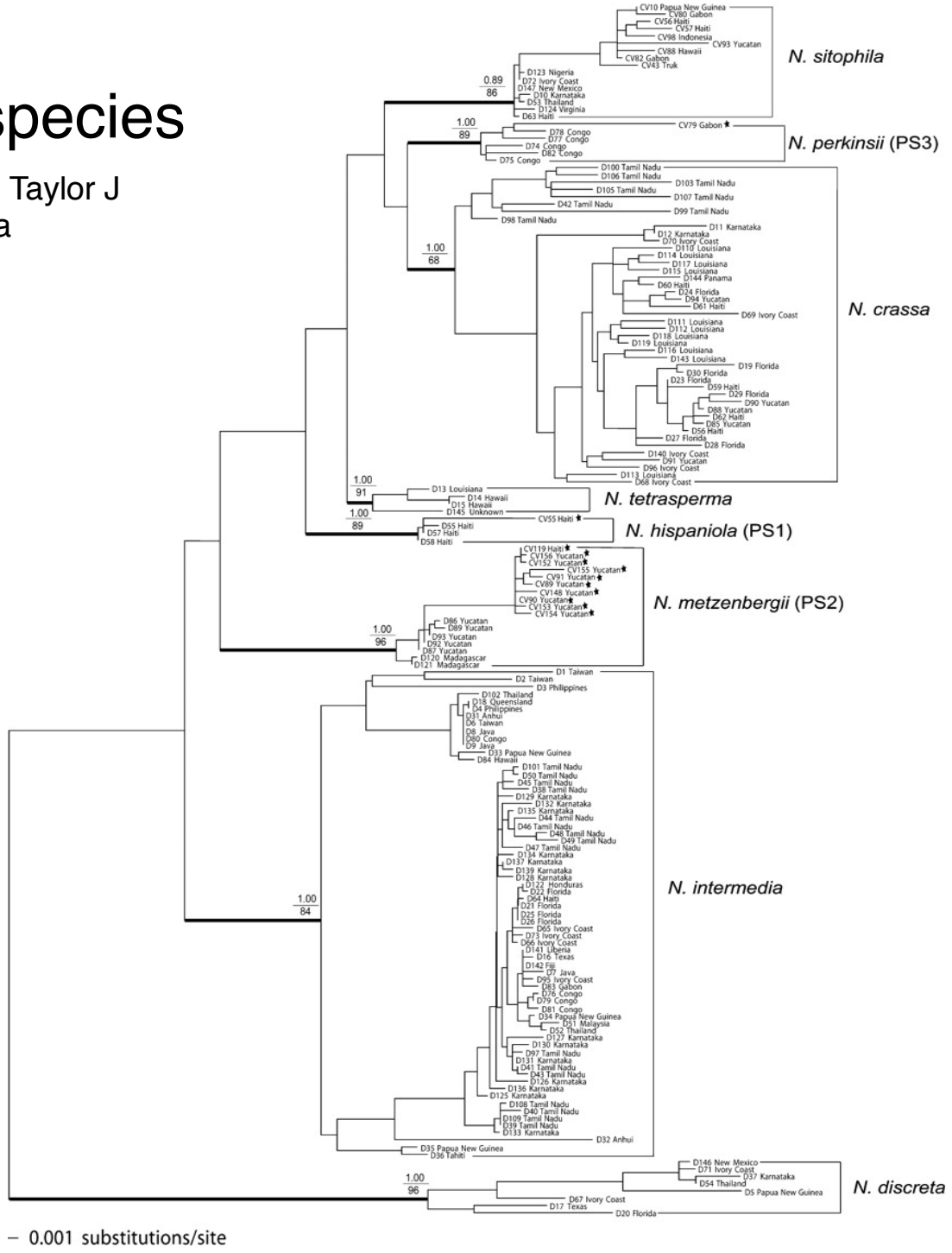
David Kowbel

Julie Walsh

Chris Ellison

Neurospora species

Villalta C, Jacobson D, Taylor J
2009 Mycologia



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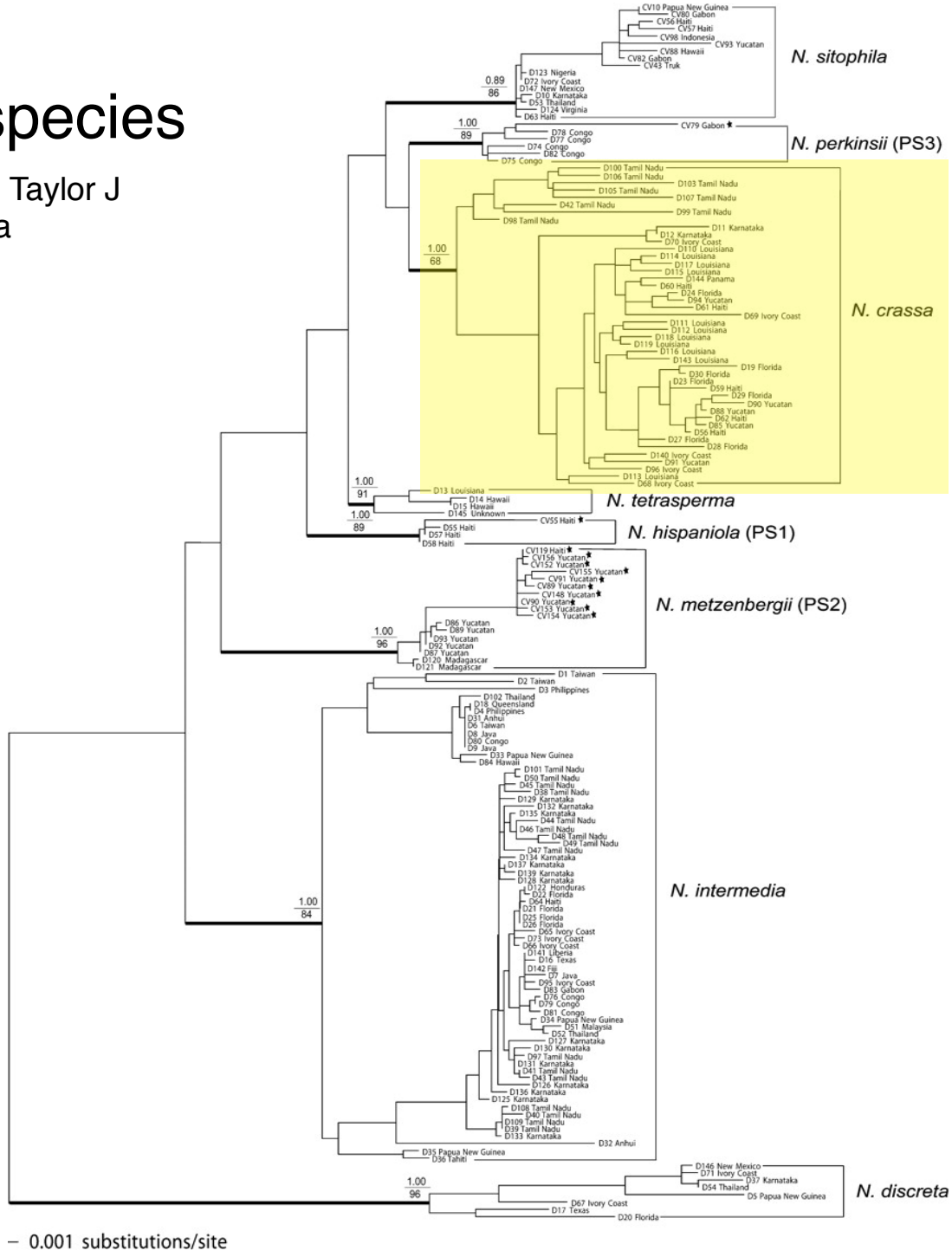
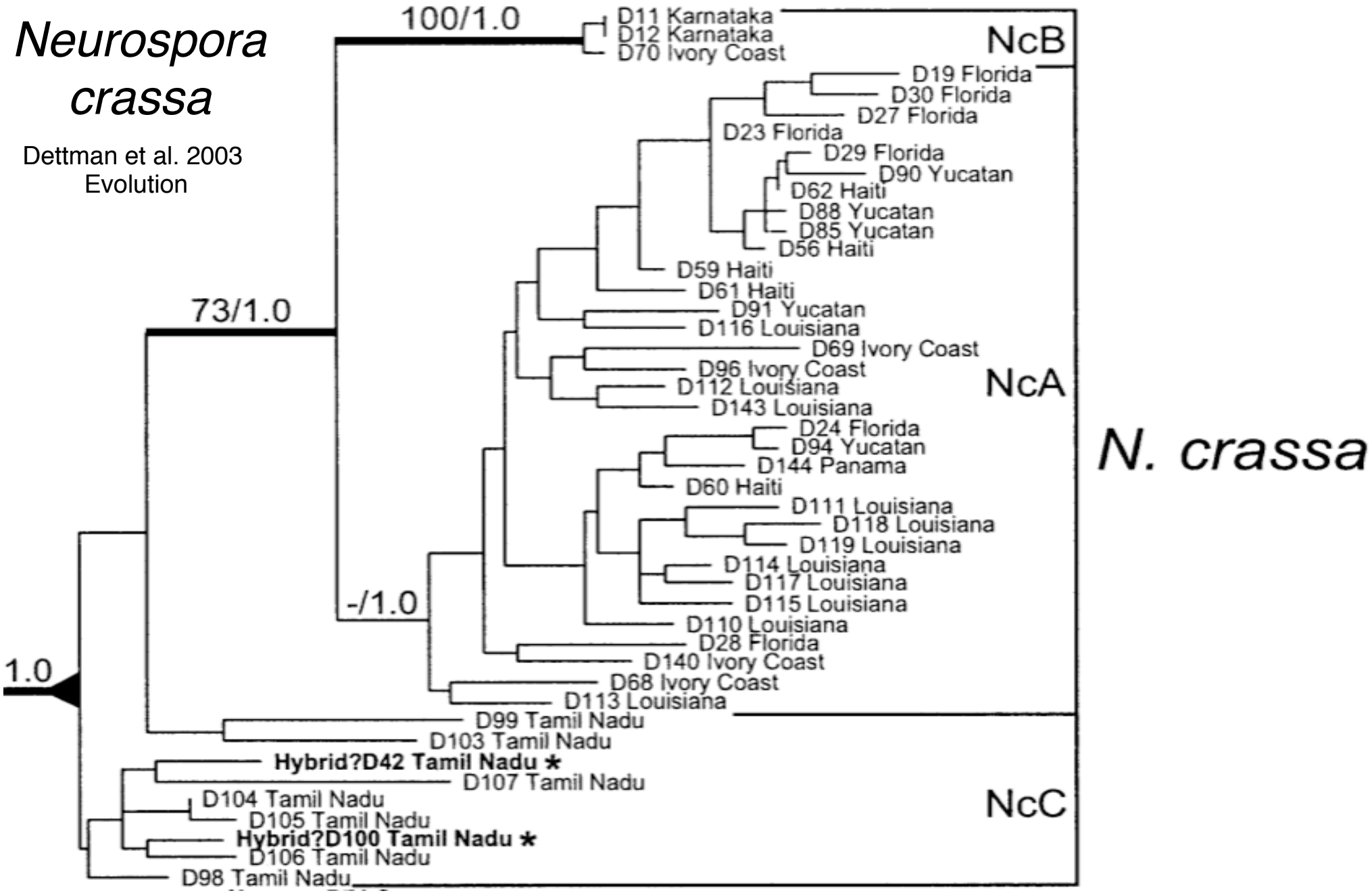
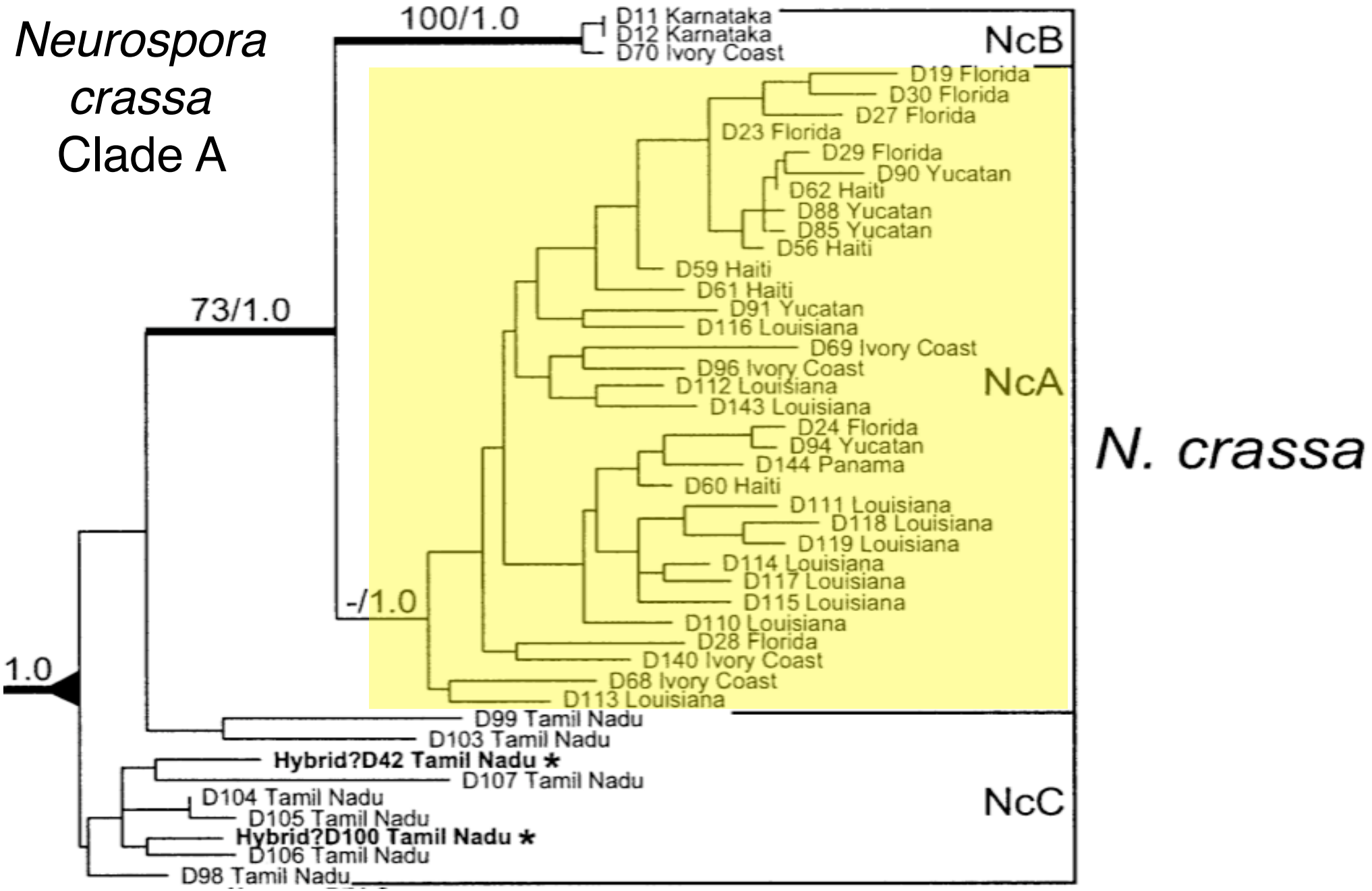


Neurospora crassa

Dettman et al. 2003
Evolution




Neurospora crassa
Clade A
100/1.0
D11 Karnataka
D12 Karnataka
D70 Ivory Coast
NcB
D19 Florida
D30 Florida
D27 Florida
D23 Florida
D29 Florida
D90 Yucatan
D62 Haiti
D88 Yucatan
D85 Yucatan
D56 Haiti
D59 Haiti
D61 Haiti
73/1.0
D91 Yucatan
D116 Louisiana
D69 Ivory Coast
D96 Ivory Coast
D112 Louisiana
NcA
D143 Louisiana
D24 Florida
D94 Yucatan
D144 Panama
D60 Haiti
D111 Louisiana
D118 Louisiana
D119 Louisiana
D114 Louisiana
D117 Louisiana
-/1.0
D115 Louisiana
D110 Louisiana
D28 Florida
D140 Ivory Coast
1.0
D68 Ivory Coast
D113 Louisiana
D99 Tamil Nadu
D103 Tamil Nadu
Hybrid?D42 Tamil Nadu *
D107 Tamil Nadu
D104 Tamil Nadu
NcC
D105 Tamil Nadu
Hybrid?D100 Tamil Nadu *
D106 Tamil Nadu
D98 Tamil Nadu
N. crassa

Genome sequence data

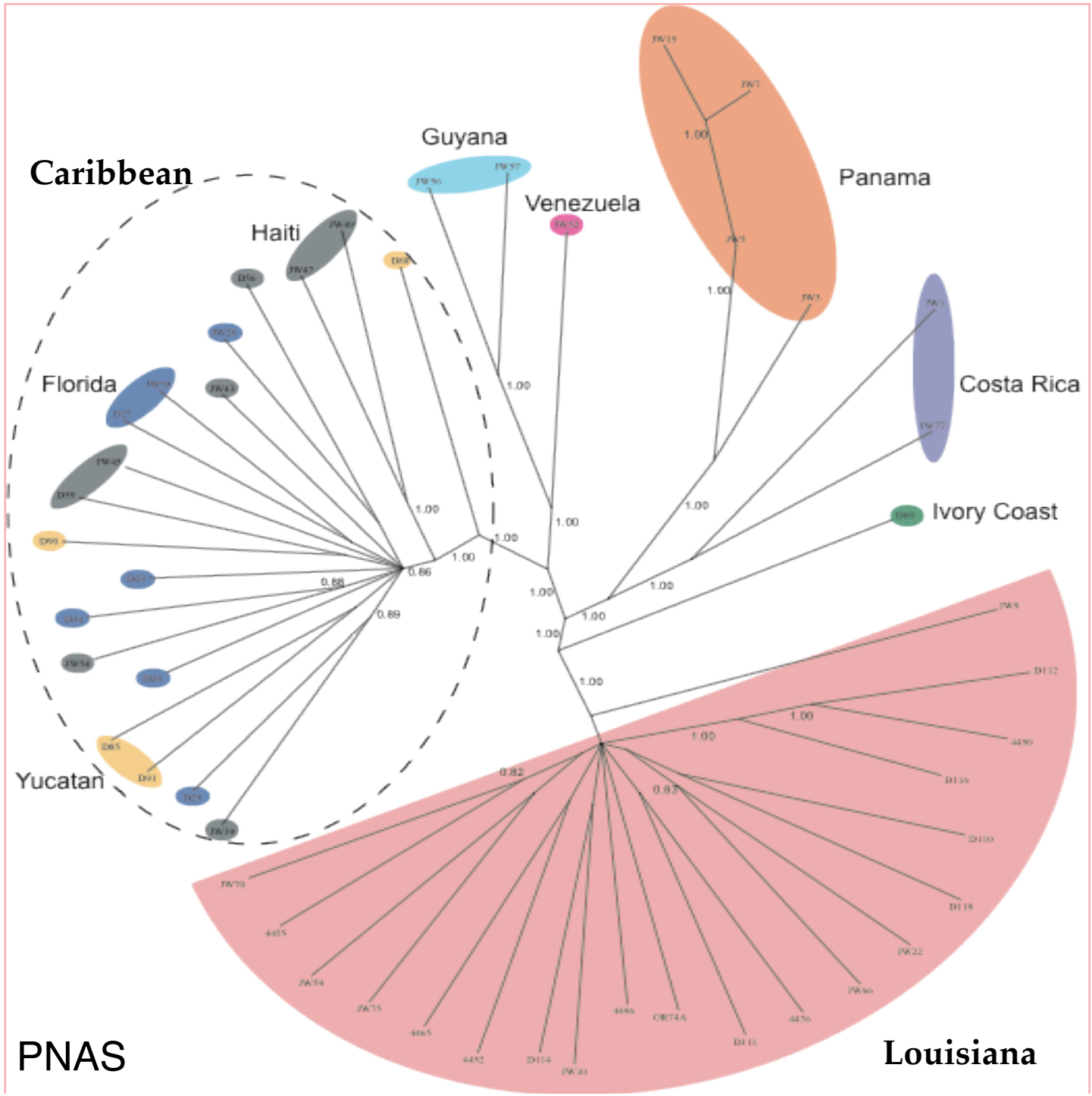
Illumina Next-Generation-Sequencing

•63 strains total

SNPs

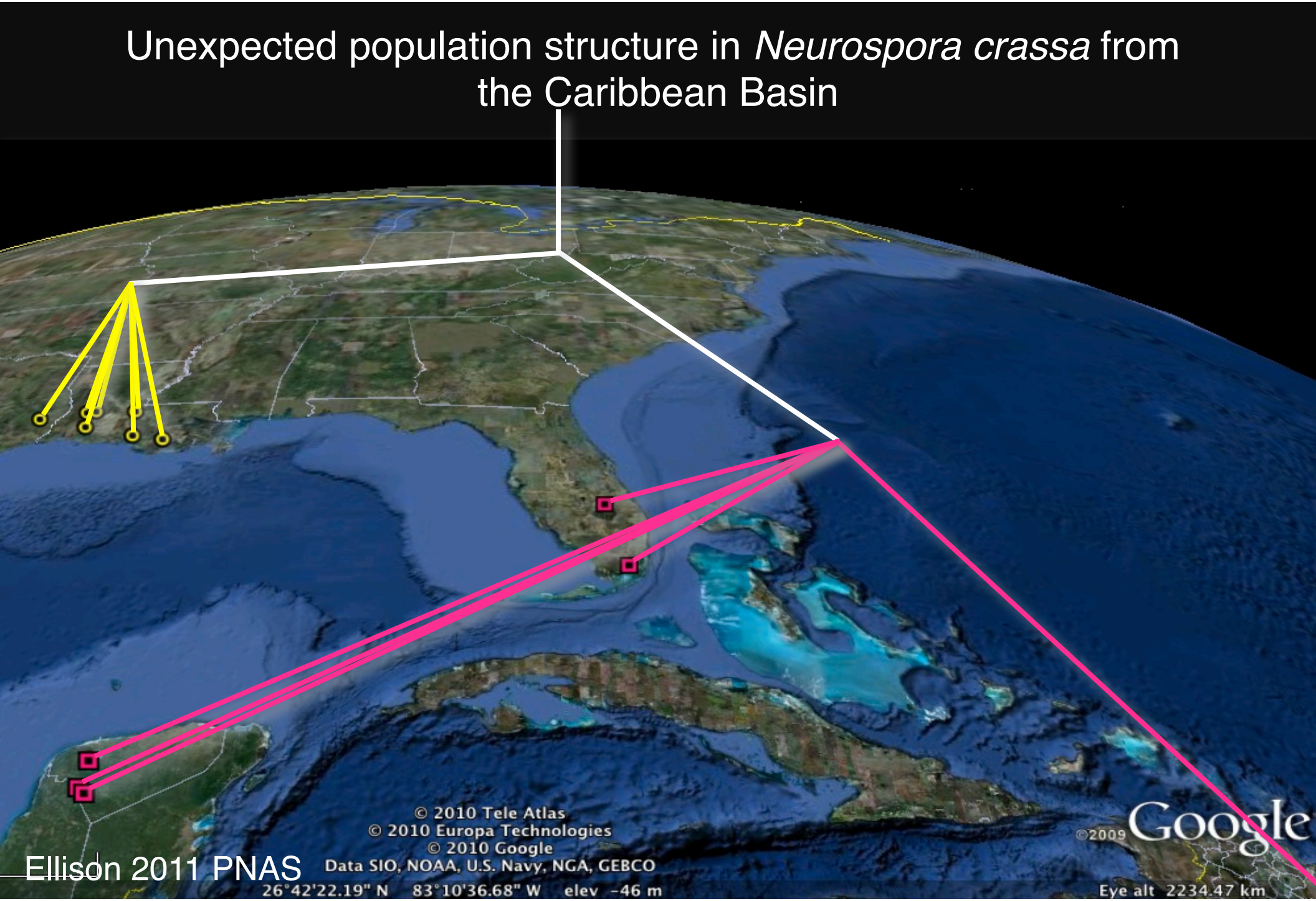
•~135,000 SNPs

• ~One every 400 nucleotides



Ellison 2011 PNAS

Unexpected population structure in *Neurospora crassa* from the Caribbean Basin

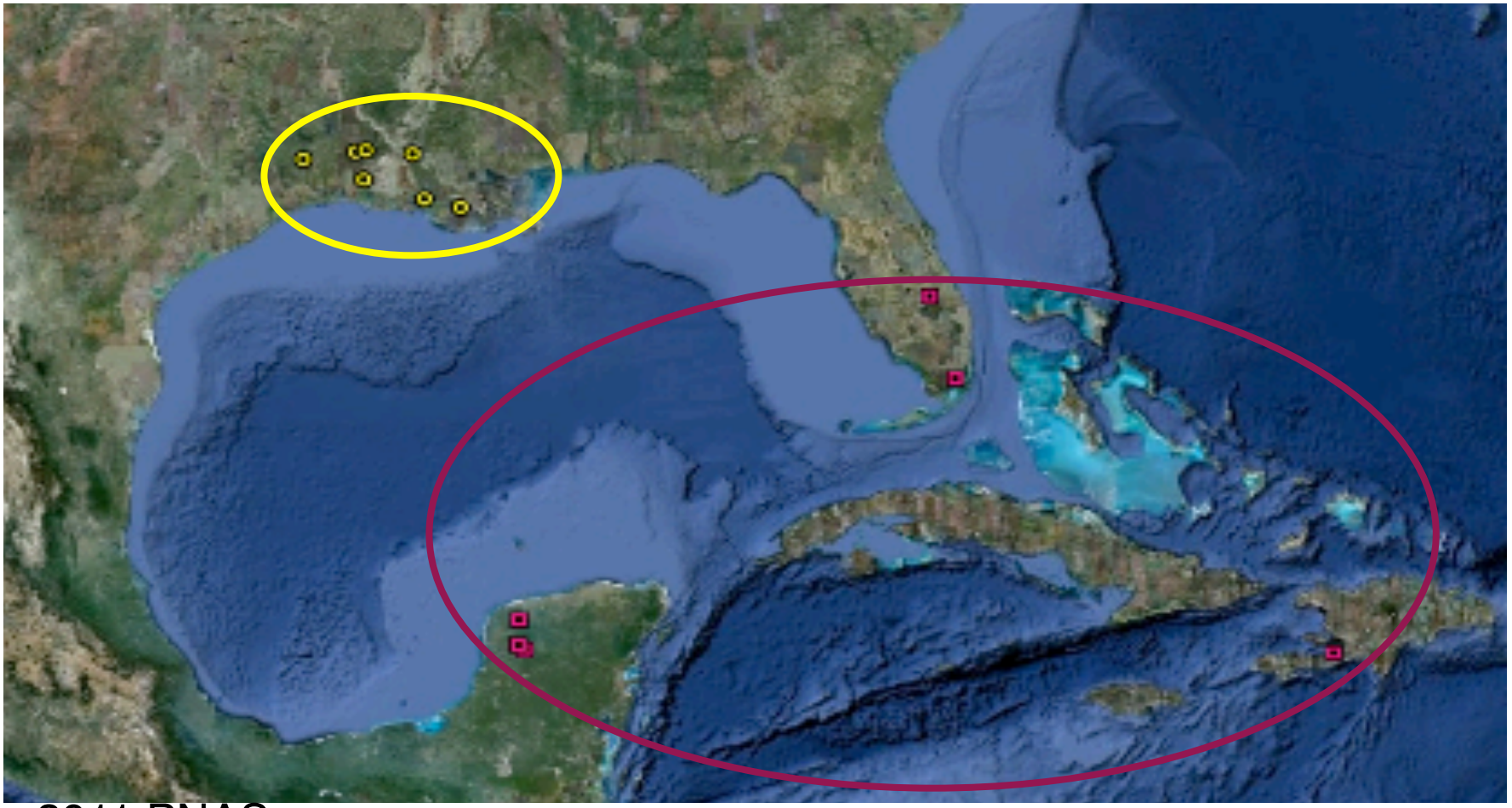


Ellison 2011 PNAS

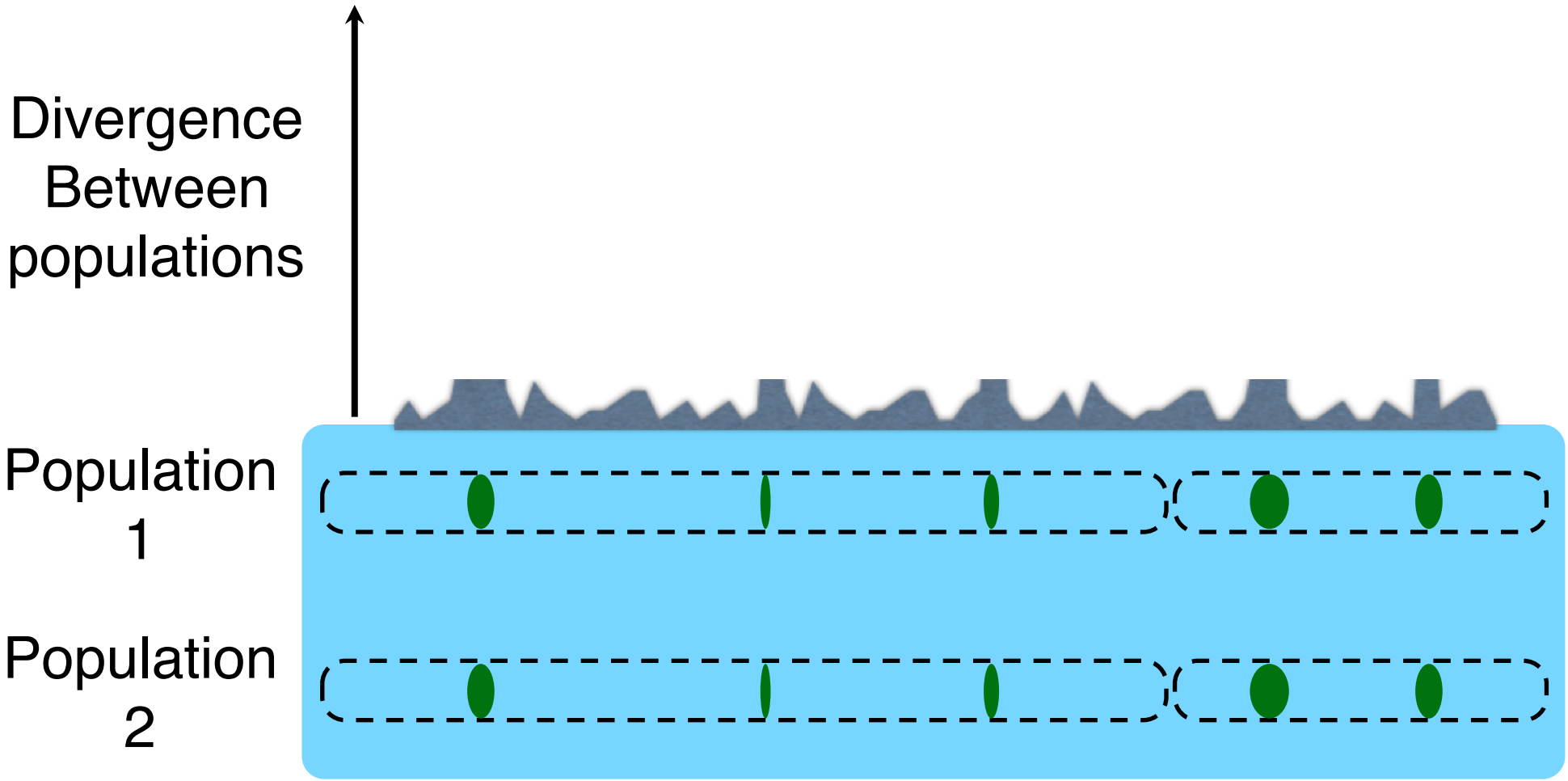
Two recently diverged populations

Temperature: 9°C difference in mean annual minimum temperature (5°C *vs* 14°C)

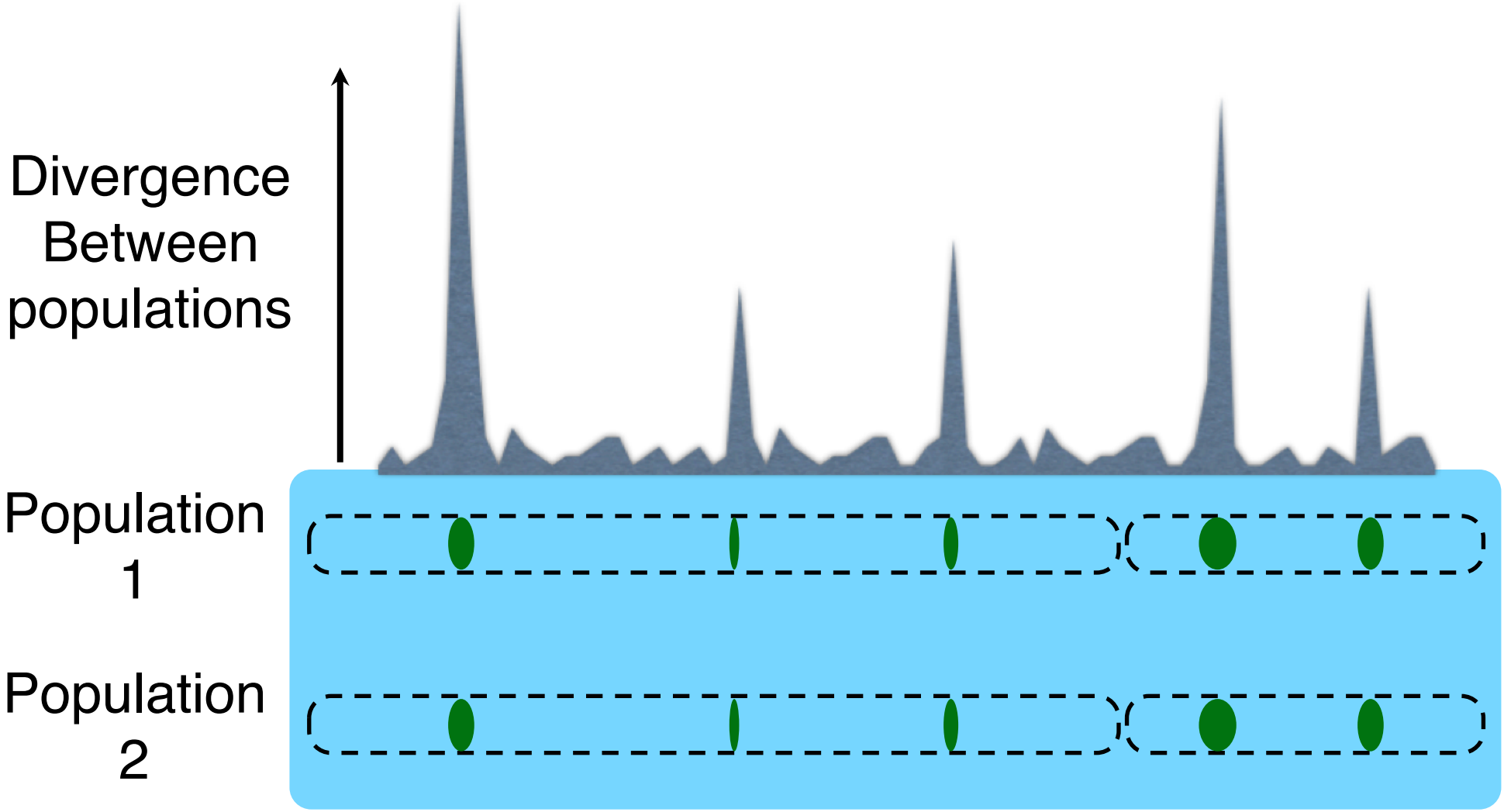
Latitude: 2.4 - 10.6 degree difference in latitude



Ellison 2011 PNAS


Divergence
Between
populations
Population
1
Population
2

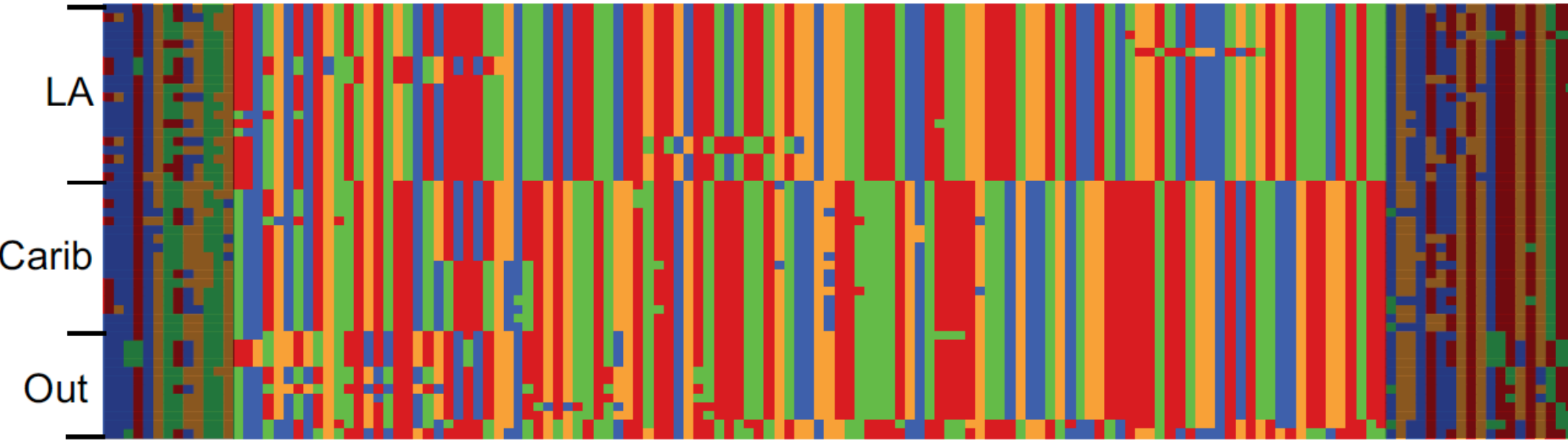
“Speciation Islands”



“Speciation Islands”

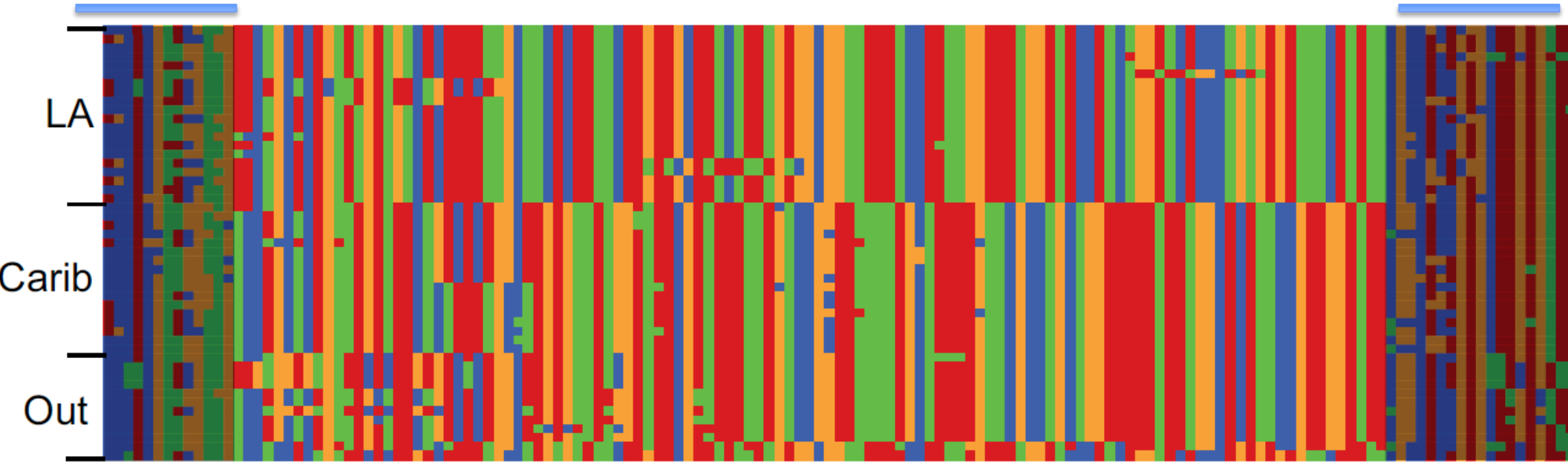
Islands of genetic differentiation in a steam of gene flow

“Islands of divergence – Speciation Islands”



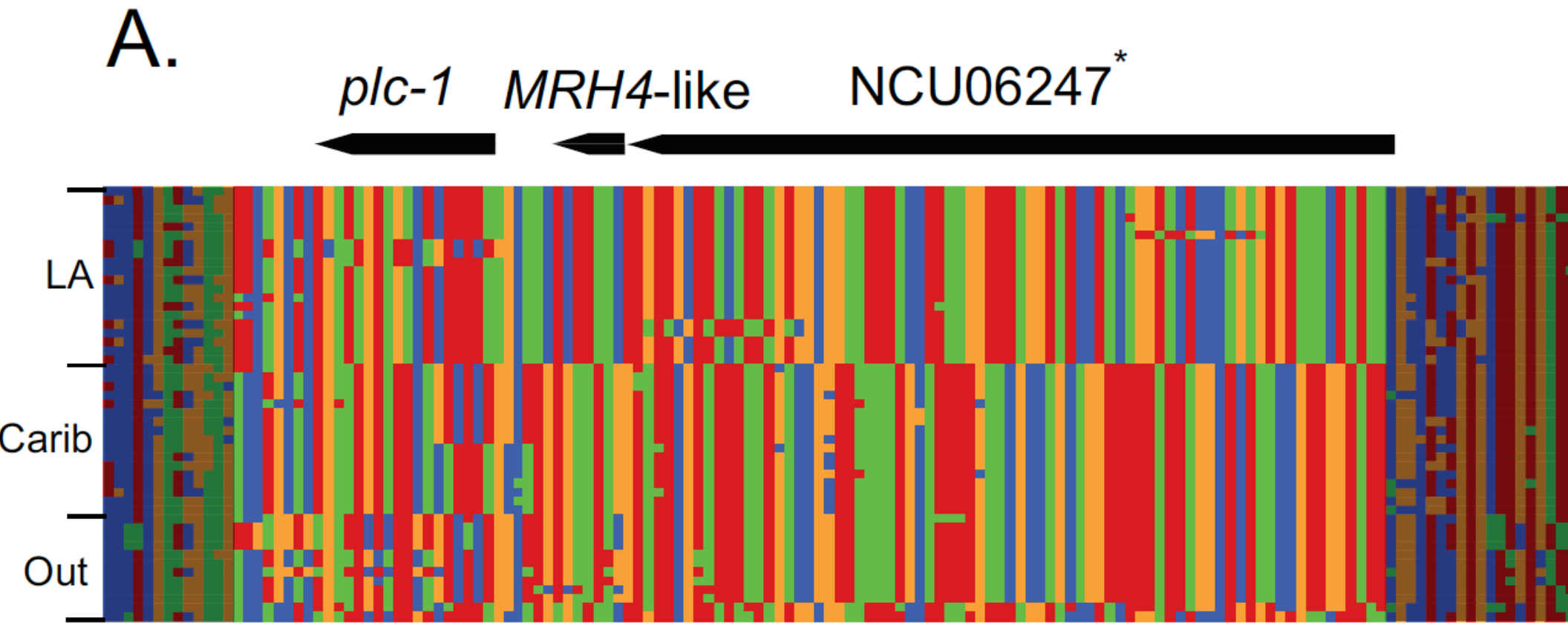
Ellison et al. 2011. PNAS

Rest of the genome



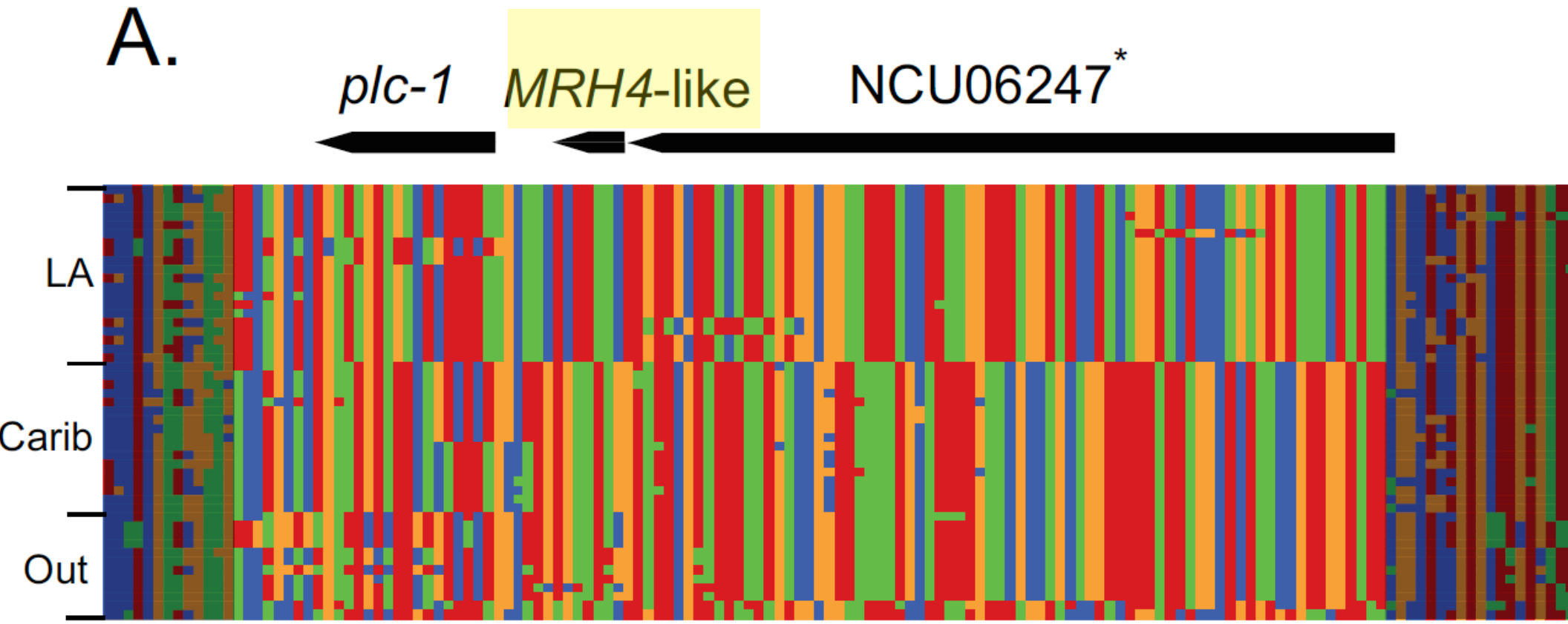
Ellison et al. 2011. PNAS

Chromosome 3 Speciation Island



Ellison 2011 PNAS

Chromosome 3 Speciation Island



Ellison 2011 PNAS

Chromosome 3 Speciation Island

MRH4-like

JOURNAL OF BACTERIOLOGY, Mar. 1999,

A Cold Shock-Induced Cyanobacterial RNA Helicase

DANUTA CHAMOT, WENDY C. MAGEE,† ESTHER YU,
AND GEORGE W. OWTTRIM*

JOURNAL OF BACTERIOLOGY, Jan. 2006,

Cold-Induced Putative DEAD Box RNA Helicases CshA and CshB Are Essential for Cold Adaptation and Interact with Cold Shock Protein B in *Bacillus subtilis*

Karen Hunger,[1]† Carsten L. Beckering,[1]† Frank Wiegeshoff,[1] Peter L. Graumann,[2] and Mohamed A. Marahiel[1]*

Property of cold inducible DEAD-box RNA helicase in hyperthermophilic archaea

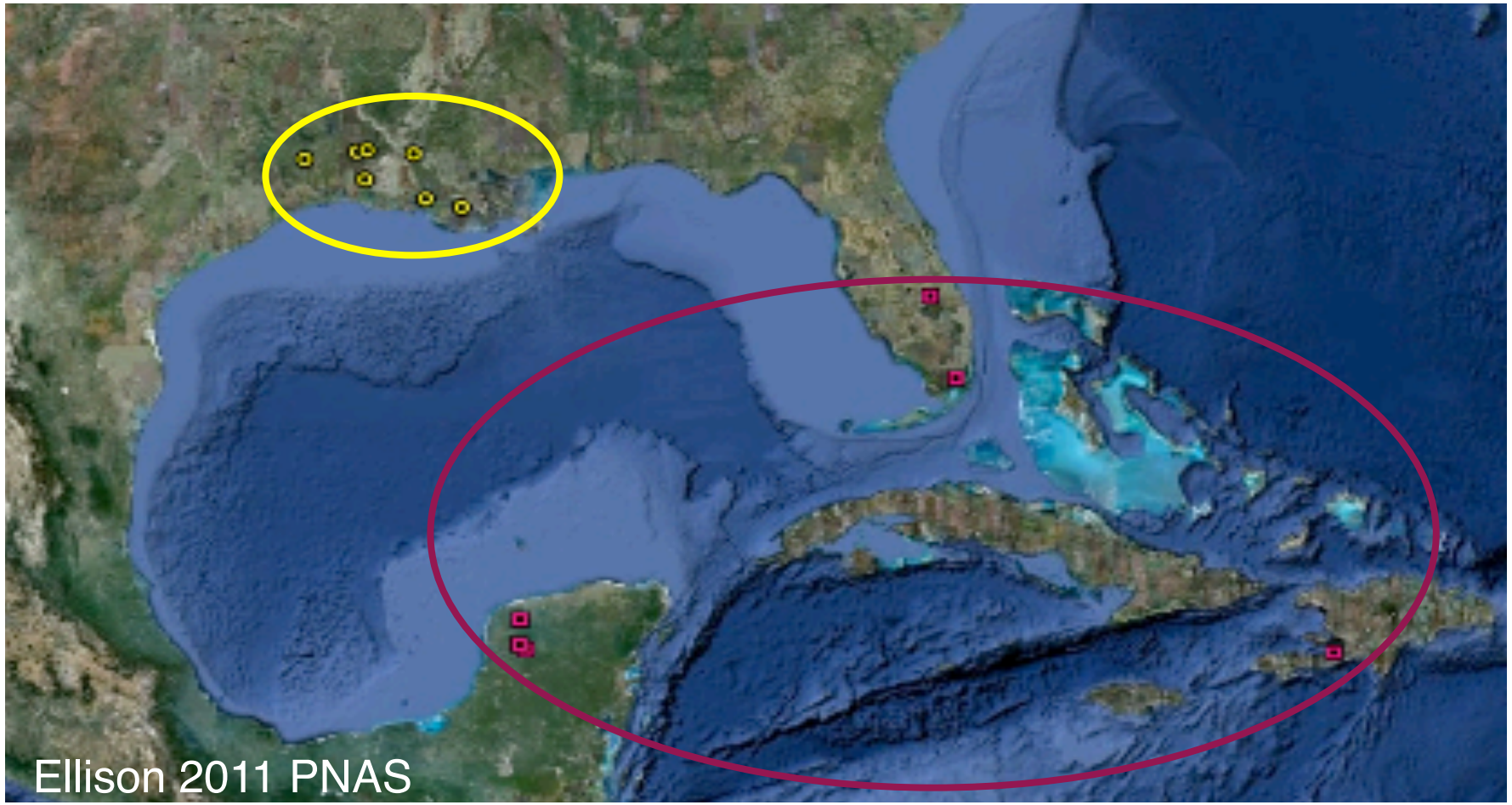
Biochemical and Biophysical Research Communications 389 (2009) 622–627

Yoko Shimada [a,1], Wakao Fukuda [a,1], Yohei Akada [a], Mayumi Ishida [a,b], Junichi Nakayama [a,b], Tadayuki Imanaka [c], Shinsuke Fujiwara [a,*]

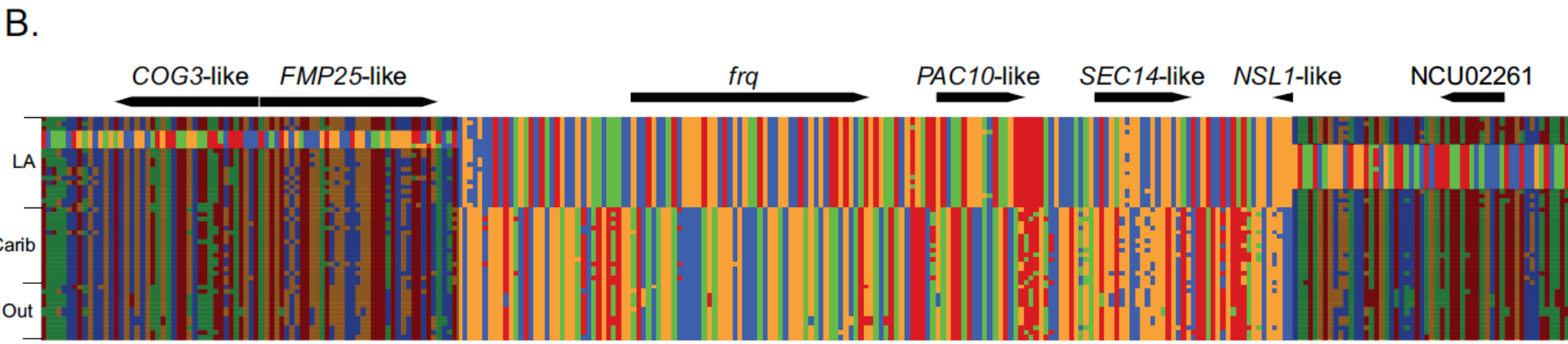
Two recently diverged populations

Temperature: 9°C difference in mean annual minimum temperature (5°C *vs* 14°C)

Latitude: 2.4 - 10.6 degree difference in latitude

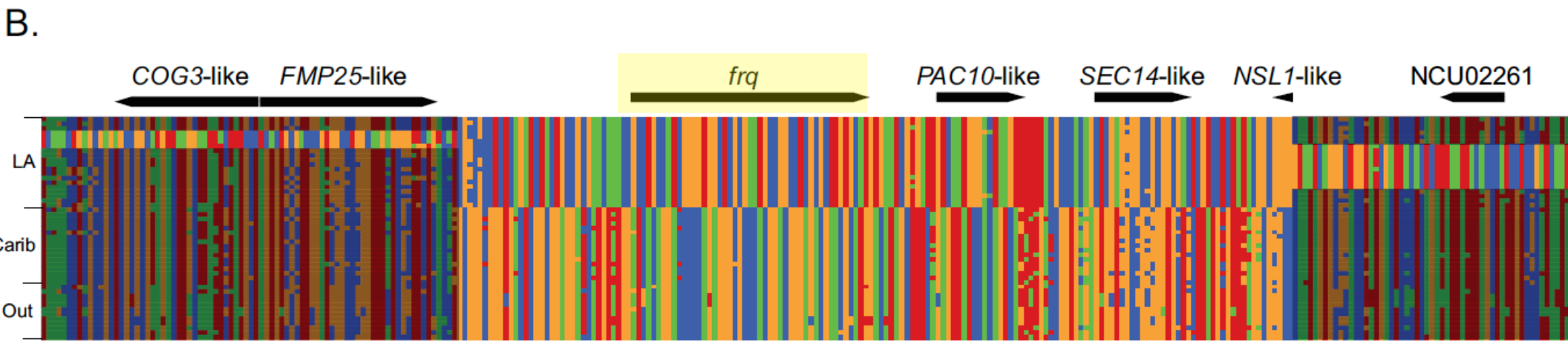


Chromosome 7 Speciation Island



Ellison 2011 PNAS

Chromosome 7 Speciation Island



Ellison 2011 PNAS

Chromosome 7 Speciation Island

frq

RESEARCH ARTICLE

Negative Feedback Defining a Circadian Clock: Autoregulation of the Clock Gene *frequency*

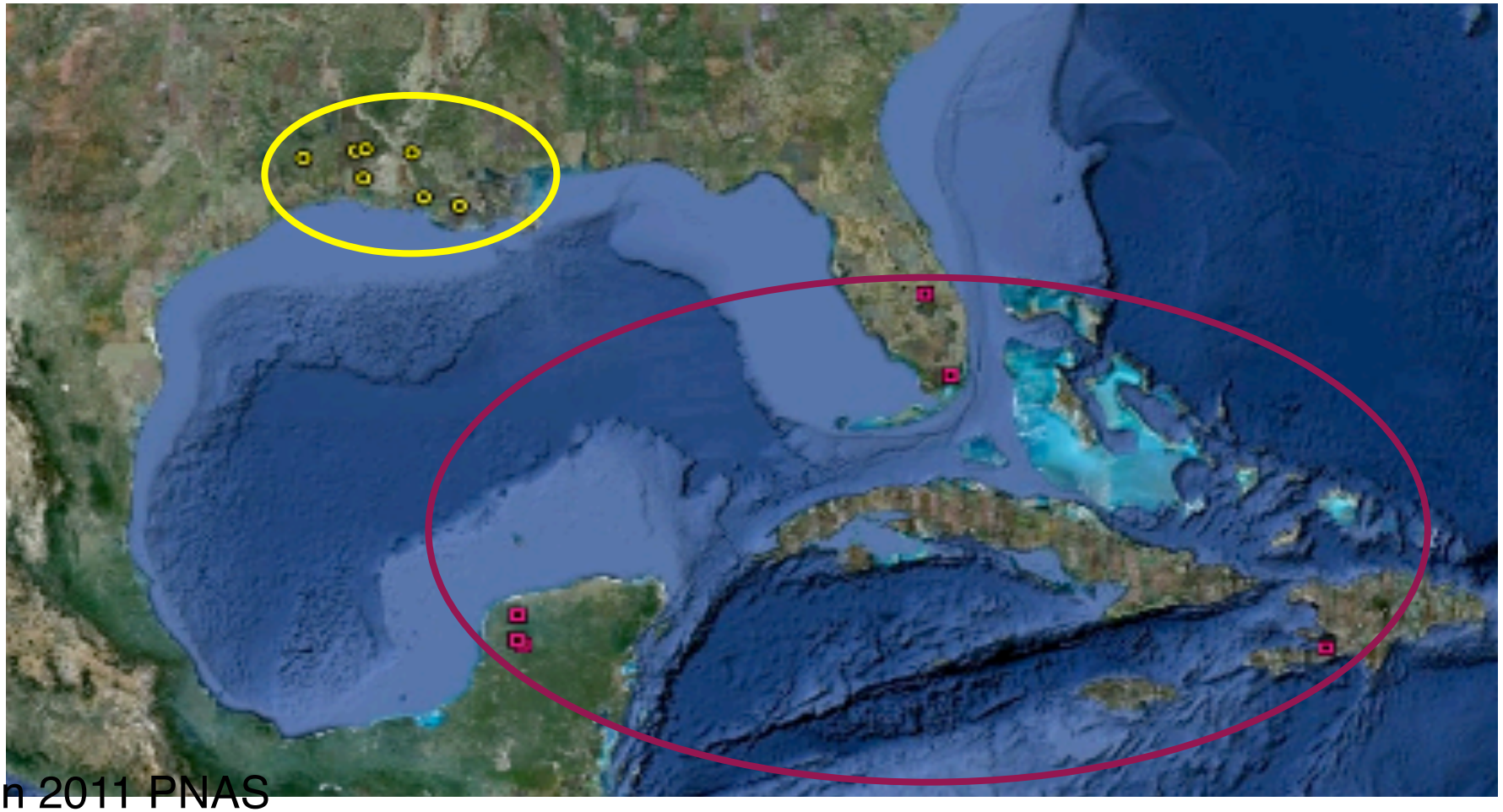
Benjamin D. Aronson, Keith A. Johnson, Jennifer J. Loros, Jay C. Dunlap*

SCIENCE • VOL. 263 • 18 MARCH 1994

Two recently diverged populations

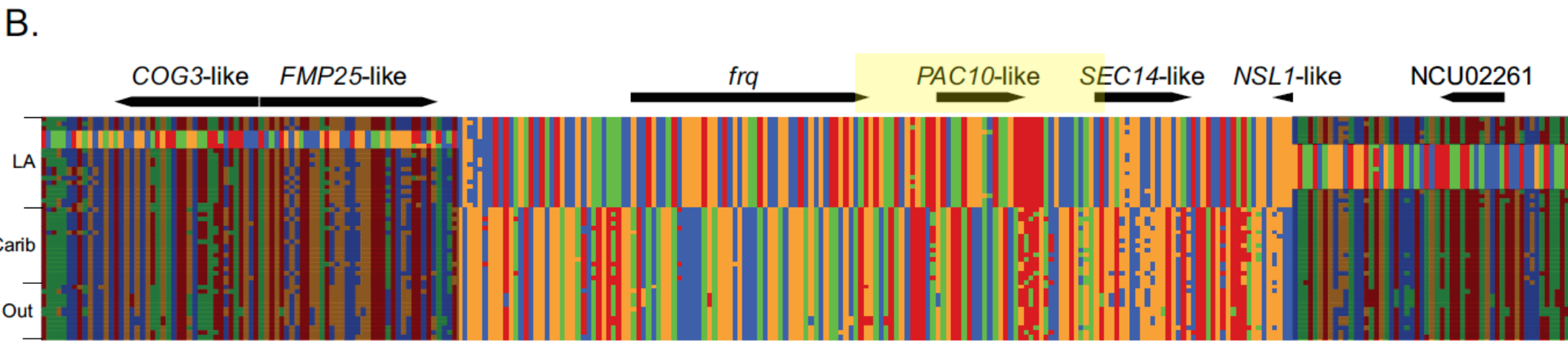
Temperature: 9°C difference in mean annual minimum temperature (5°C *vs* 14°C)

Latitude: 2.4 - 10.6 degree difference in latitude



Ellison 2011 PNAS

Chromosome 7 Speciation Island



Works with chaperones to fold cytoskeleton proteins

Ellison 2011 PNAS

Cell, Vol. 93, 863–873, May 29, 1998, Copyright ©1998 by Cell Press

Prefoldin, a Chaperone that Delivers Unfolded Proteins to Cytosolic Chaperonin

Irina E. Vainberg,*§‖ Sally A. Lewis,*‖
Heidi Rommelaere,† Christophe Ampe,†
Joel Vandekerckhove,† Hannah L. Klein,*
and Nicholas J. Cowan*‡

The EMBO Journal Vol.17 No.4 pp.952–966, 1998

A novel protein complex promoting formation of functional α- and γ-tubulin

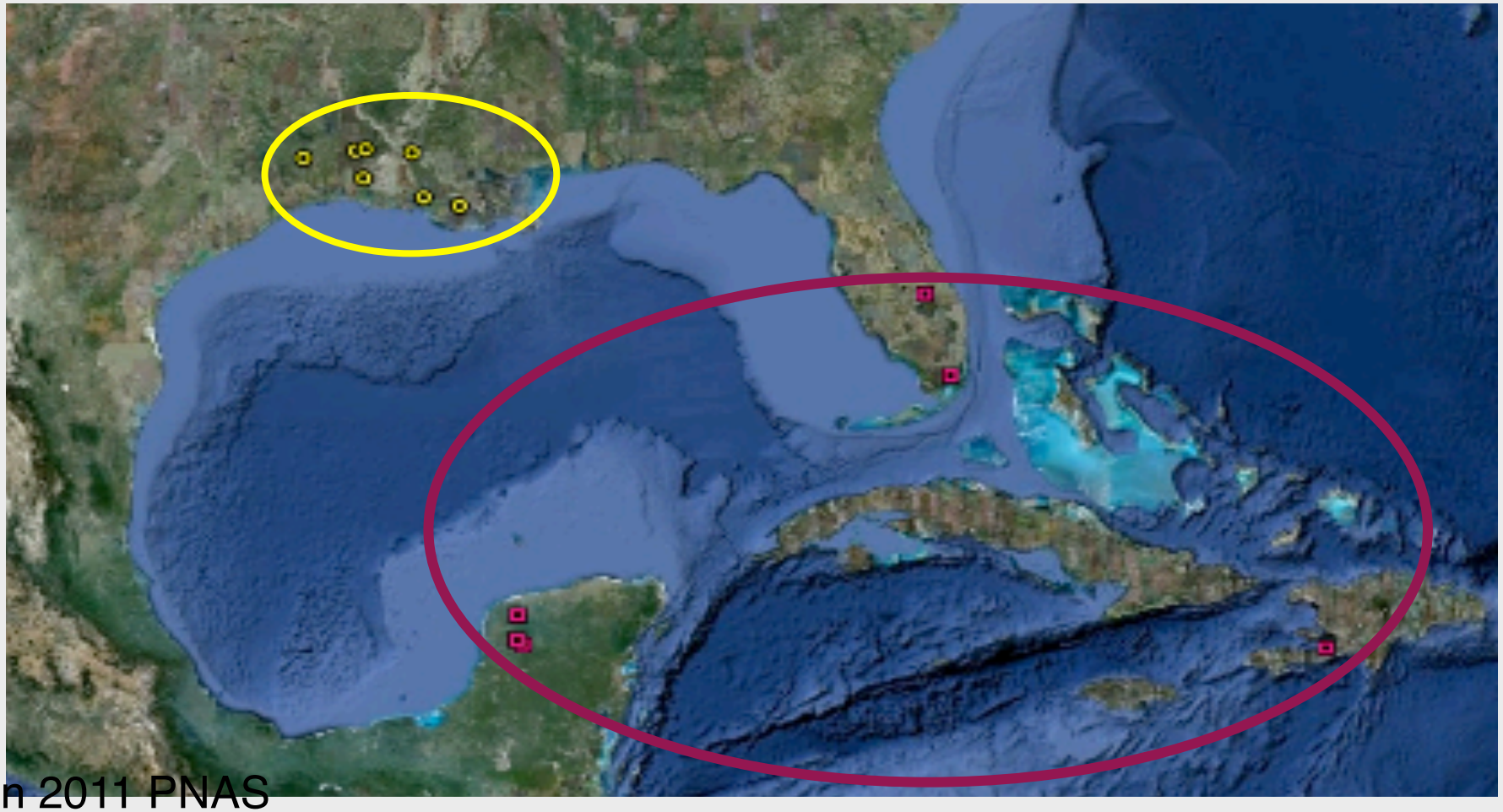
Silke Geissler, Katja Siegers[1] and Elmar Schiebel[1,2]

PAC10 rescue[s] . . . cold-sensitivity . . . of the yeast deletion mutants.

Louisiana v. Caribbean

Temperature: 9°C difference in lowest annual temp - 5°C *v.* 14°C

Latitude: 2.4° - 10.6° difference in latitude

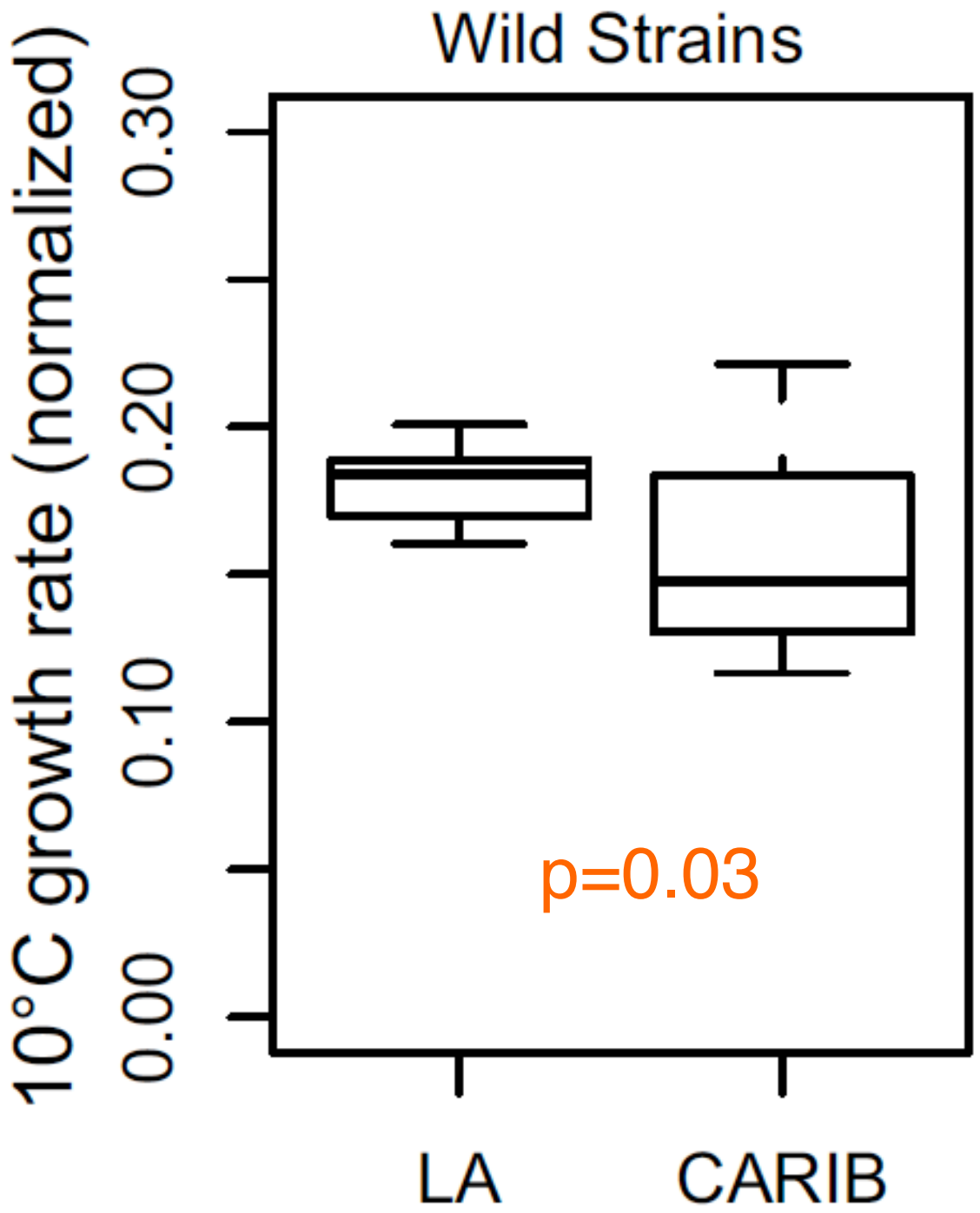


Ellison 2011 PNAS

Growth at 10˚C

Growth at 25˚C

N. crassa
wild strains



Ellison et al. 2011. PNAS

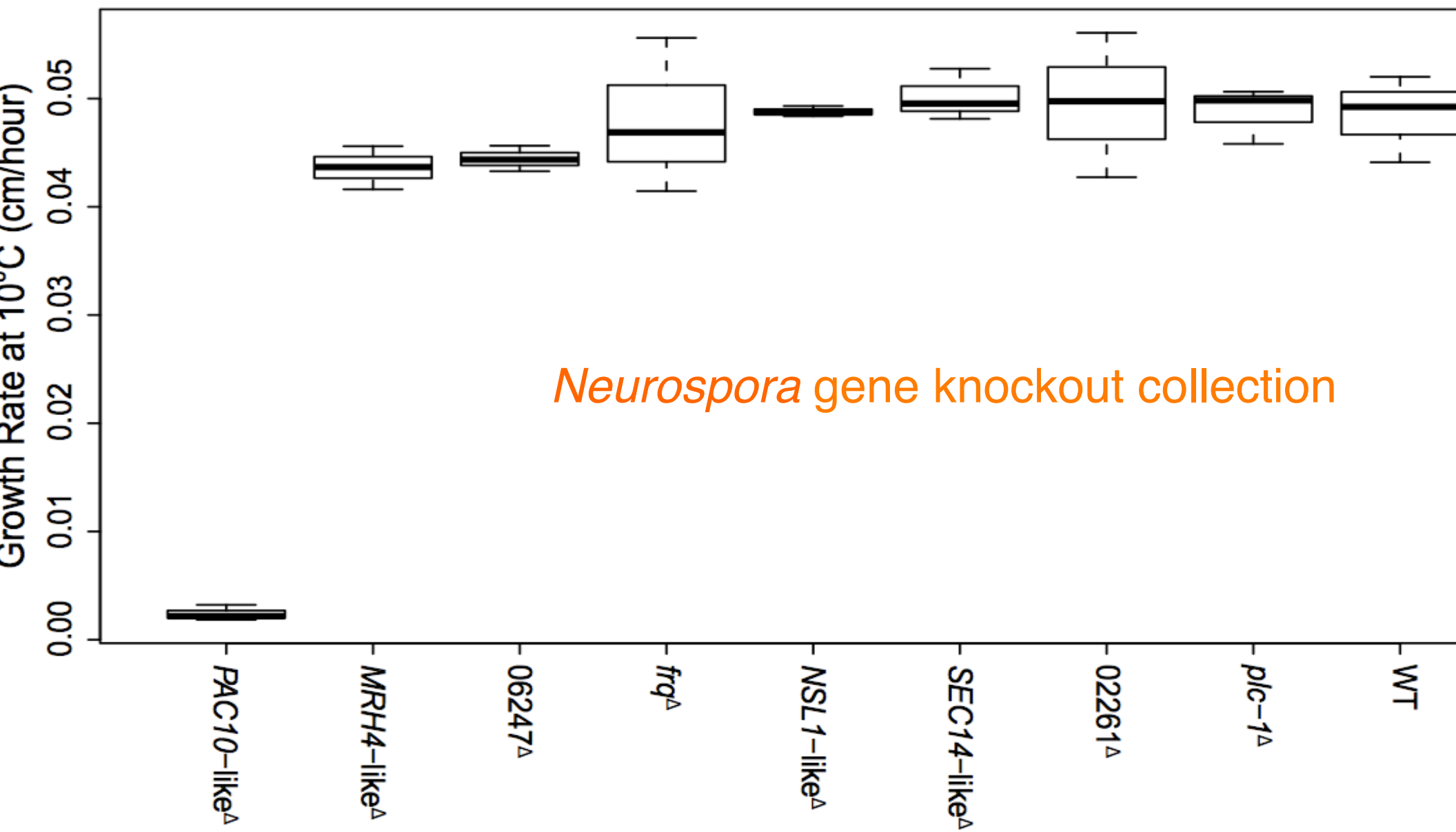
A high-throughput gene knockout procedure for *Neurospora* reveals functions for multiple transcription factors

Hildur V. Colot*†, Gyungsoon Park†‡, Gloria E. Turner§, Carol Ringelberg*, Christopher M. Crew‡¶, Liubov Litvinkova‡, Richard L. Weiss§, Katherine A. Borkovich‡, and Jay C. Dunlap*‖

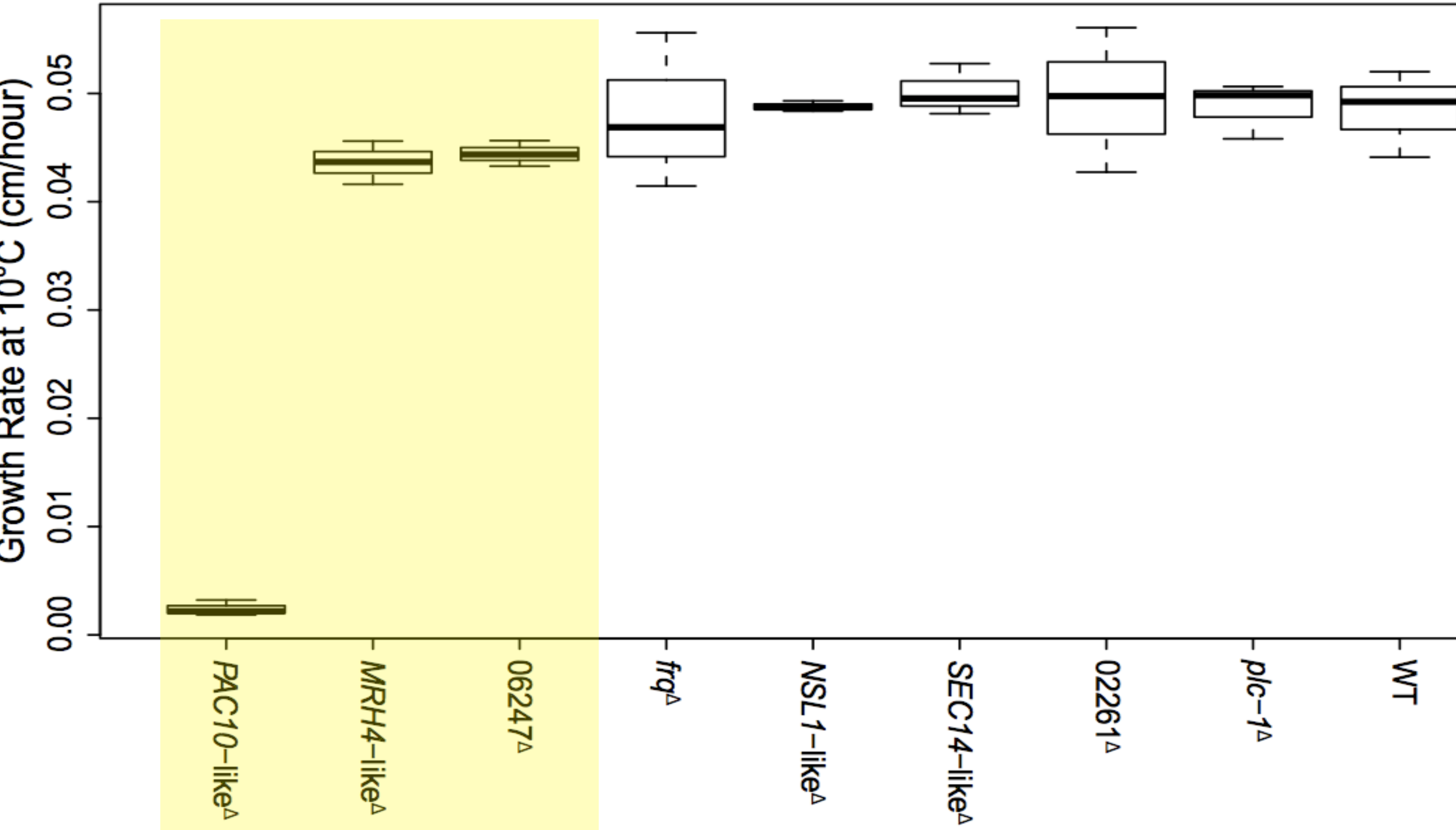
*Department of Genetics, Dartmouth Medical School, HB7400, Hanover, NH 03755; ‡Department of Plant Pathology, University of California, Riverside, CA 92521; and §Department of Chemistry and Biochemistry, 405 Hilgard Avenue, University of California, Los Angeles, CA 90095

Edited by David D. Perkins, Stanford University, Stanford, CA, and approved March 29, 2006 (received for review February 21, 2006)

10352–10357 | PNAS | July 5, 2006 | vol. 103 | no. 27



Ellison et al. 2011. PNAS

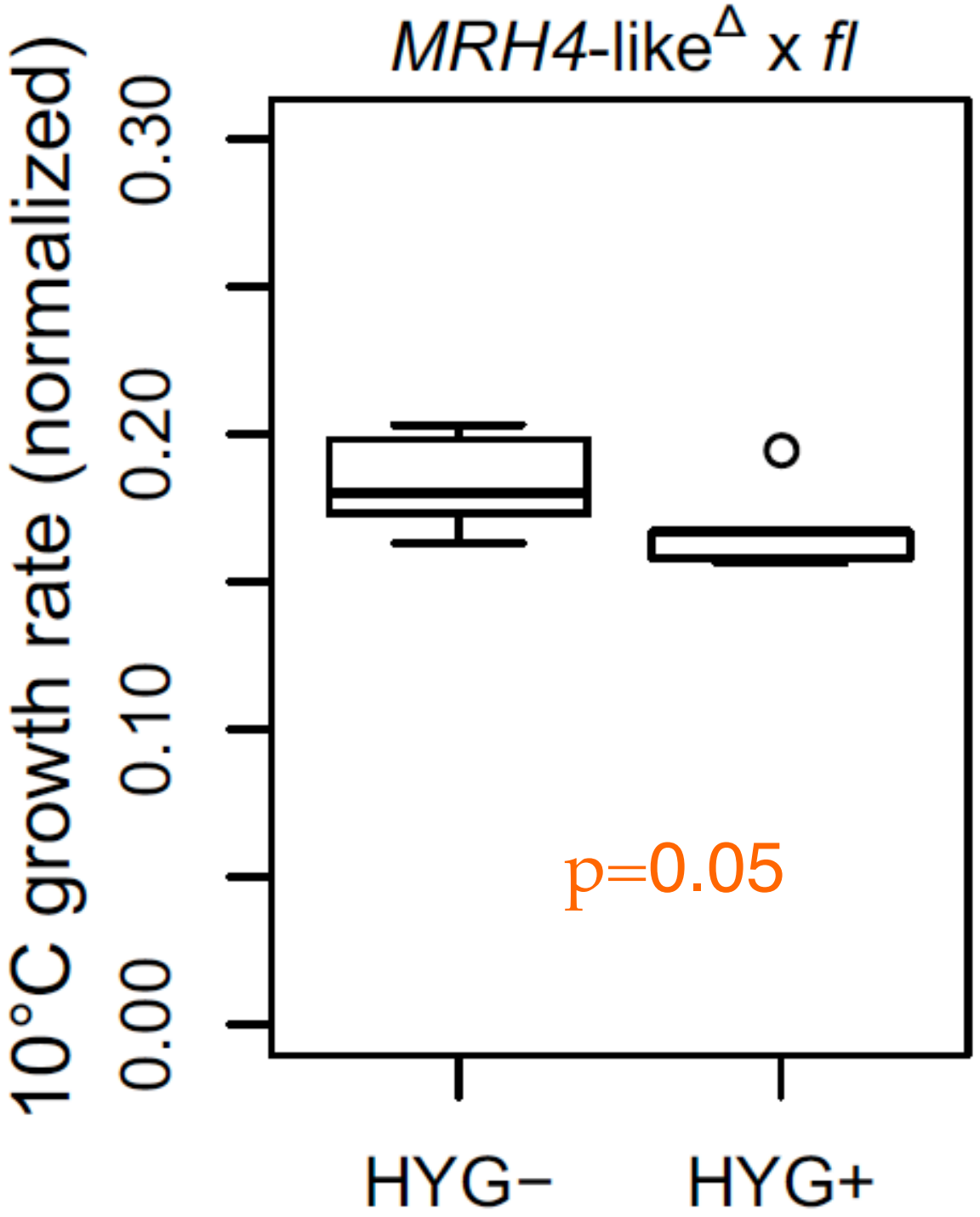


Ellison et al. 2011. PNAS

Growth at 10˚C

Growth at 25˚C

RNA helicase

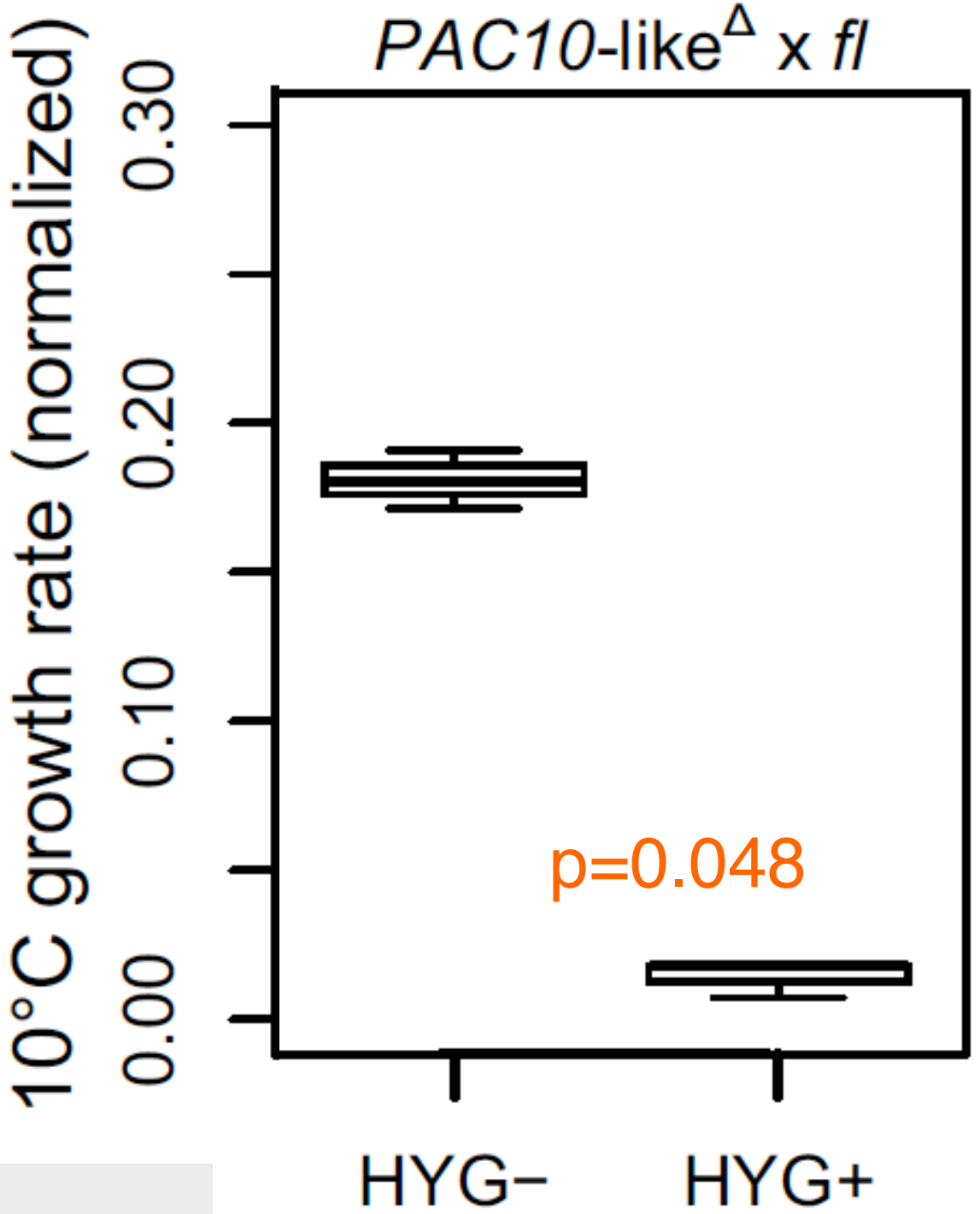


Ellison et al. 2011. PNAS

Growth at 10˚C

Growth at 25˚C

Pre foldin



Ellison et al. 2011. PNAS

What environmental factor?
What Phenotype?
Which genes?

Genes:
Cold Shock RNA helicase.
Prefoldin chaperone.
Circadian Clock Oscillator.

Environmental factors:
Minimum temperature.
Day length.

Growth as the phenotype

Genes:

Cold Shock RNA helicase.

Prefoldin chaperone.

Circ ator.

Reverse Ecology

E s:

M e.

Day length.

Growth as the phenotype

Medicine – Fungi That Cause Systemic Disease

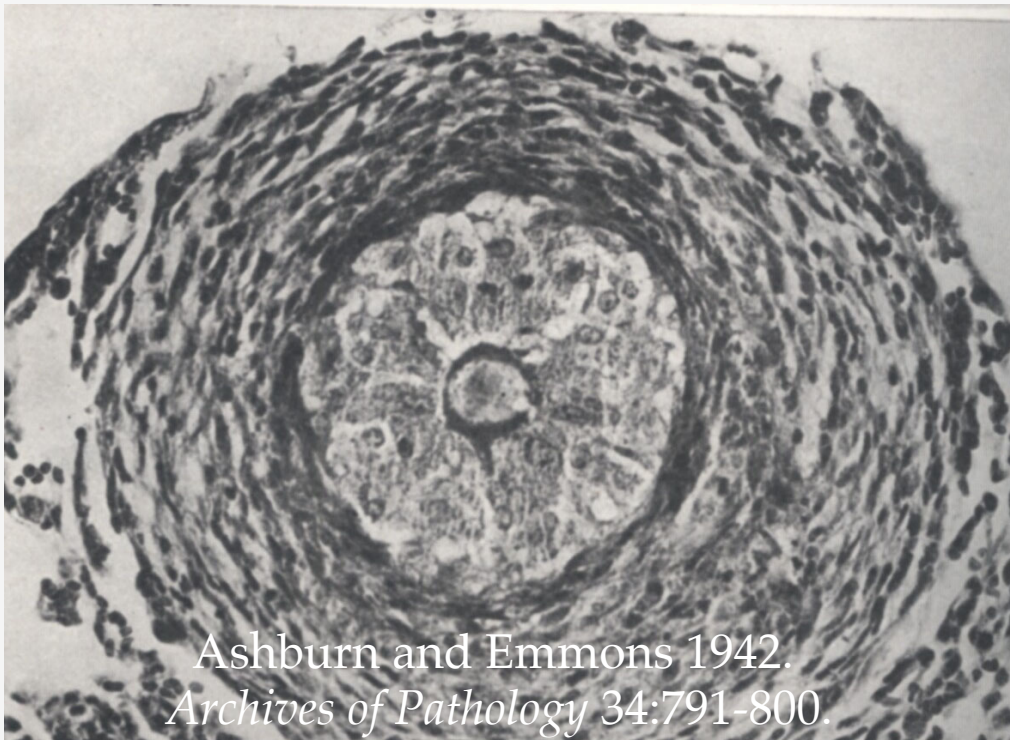
San Joaquin Valley Fever Fungus
Coccidioides immitis

Arizona Valley Fever Fungus
Coccidioides posadasii

Medicine – Fungi That Cause Systemic Disease

San Joaquin Valley Fever Fungus
Coccidioides immitis

Arizona Valley Fever Fungus
Coccidioides posadasii



Ashburn and Emmons 1942.
Archives of Pathology 34:791-800.

Biofuels – Yeasts to Make Ethanol at High Temperature

Thermophilic yeasts

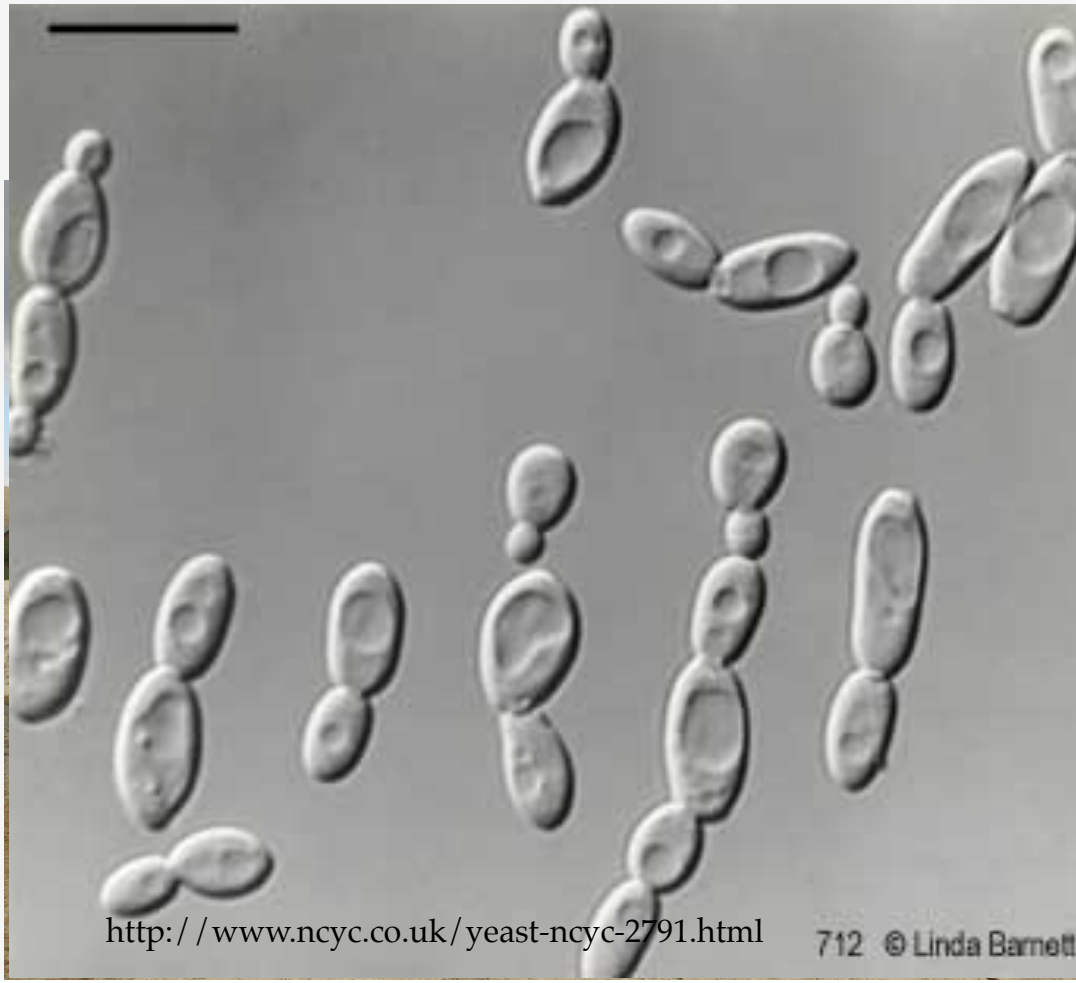
Kluyveromyces marxianus
Issatchenkia orientalis

Bagasse Pile in Louisiana

Biofuels – Yeasts to Make Ethanol at High Temperature

Thermophilic yeasts

Kluyveromyces marxianus
Issatchenkia orientalis



Ecology – Fungi that from Mutualistic Symbioses with Plants

Ectomycorrhizal Fungus *Suillus brevipes*

Ecology – Fungi that from Mutualistic Symbioses with Plants

Ectomycorrhizal Fungus
Suillus brevipes

What are Fungi?

Where are Fungi in the Tree of Life?

Adaptation.

Great recent talk on human genomic medicine

http://pmb.berkeley.edu/regentslecture

Genomic Medicine Challenge: Translating Basic Research

Watch the Video of Regents' Lecture by Thomas White, Biotech Pioneer

Video of 1/24 Lecture by Thomas White

On Thursday, Jan. 24 Thomas J. White gave a fascinating lecture to a packed crowd in Stanley Hall on the UC Berkeley campus.

The lecture was part of the prestigious Regents' Lecture series presented by the University, and features scholars whose careers in arts, letters, science or business have been at least in part outside academia, and has been an annual feature of Berkeley campus life for over 50 years.

Dr. White discussed genomic medicine and its practical applications in terms of economics, laws and politics, as well as science. Dr. White has more than 30 years of experience in medical biotechnology, evenly divided among three Bay Area firms:

- Chris Ellison
- Rachel Brem
- Louise Glass
- Charles Hall
- David Kowbel
- Juliet Welch
- David Jacobson

Chang-Lin Tien
Graduate Fellowship

Questions?