

9. Niches and Evolution

Jasper Slingsby, BIO2014F

2025-05-09

...species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure..."

Darwin 1859

Relatedness

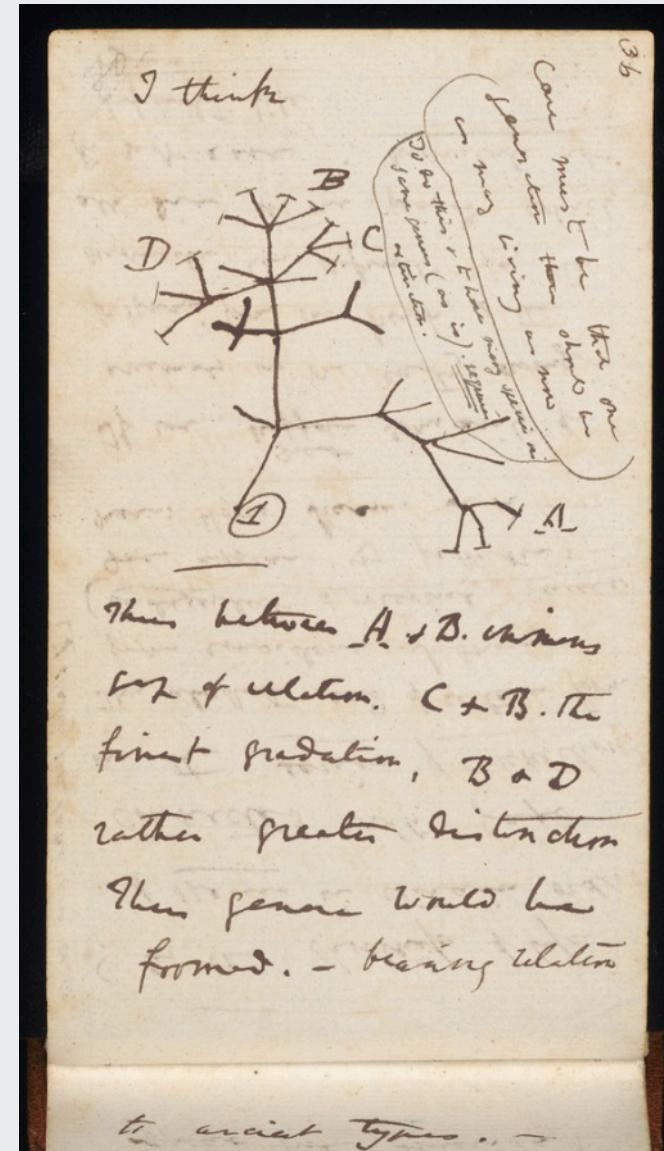
While it seems obvious now, it took a long time for people to realise that the similarity among some species that we observe is because they have descended from a common ancestor.

- i.e. They were once identical, because they were once the same thing!

The degree to which they differ is a function of:

- time since they diverged
- genetic variation (including mutation rates)
 - opportunity for change
- genetic and developmental constraints
 - constraints on change
- selective pressure
 - the need to change (or not)

The first phylogeny. From Darwin's Notebook B.



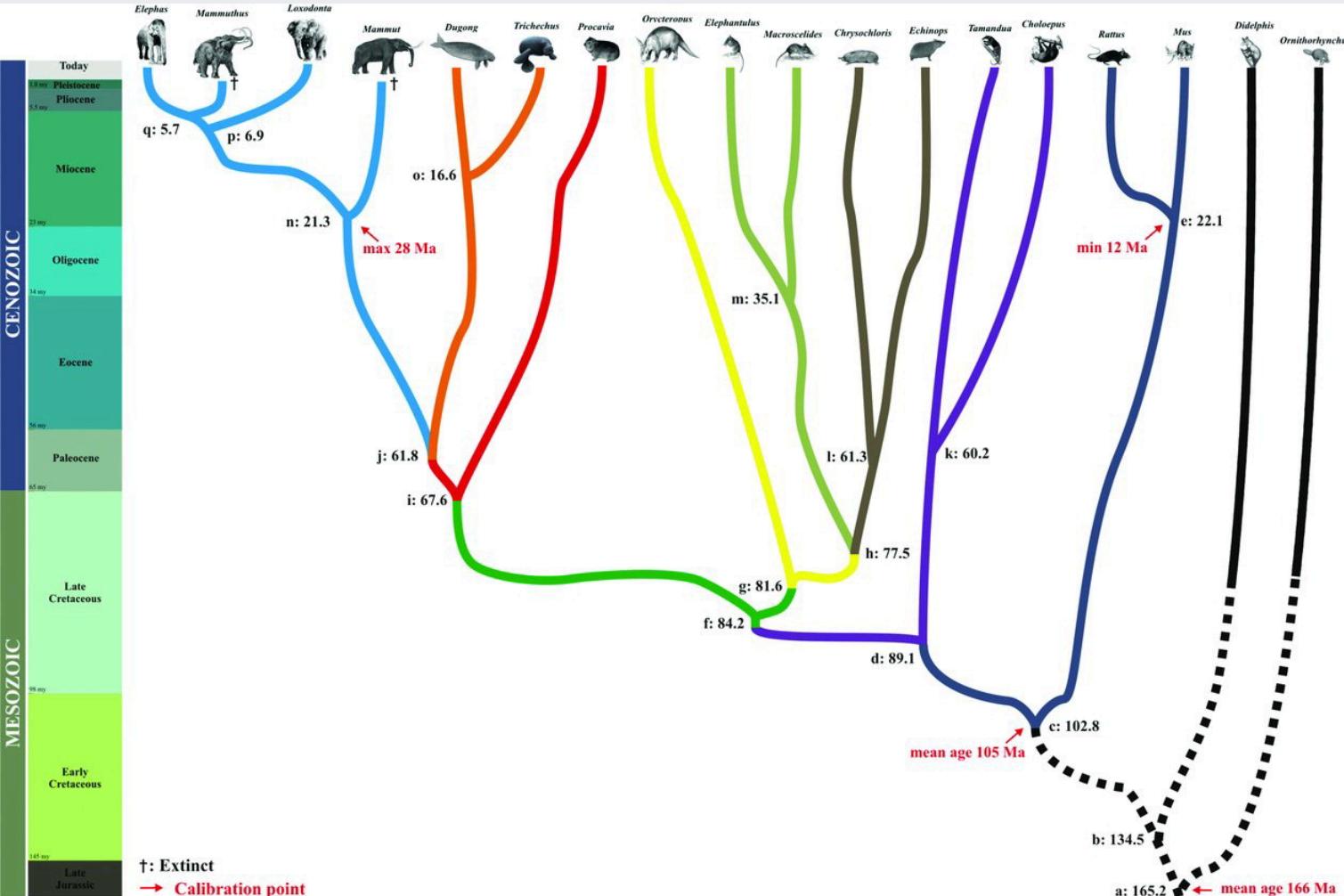


Who is the elephant's closest ancestor?



Tapir: guyincognito; Dugong: Dennis Rabeling

Quite a bit of divergence, but then it has been 60+ million years...



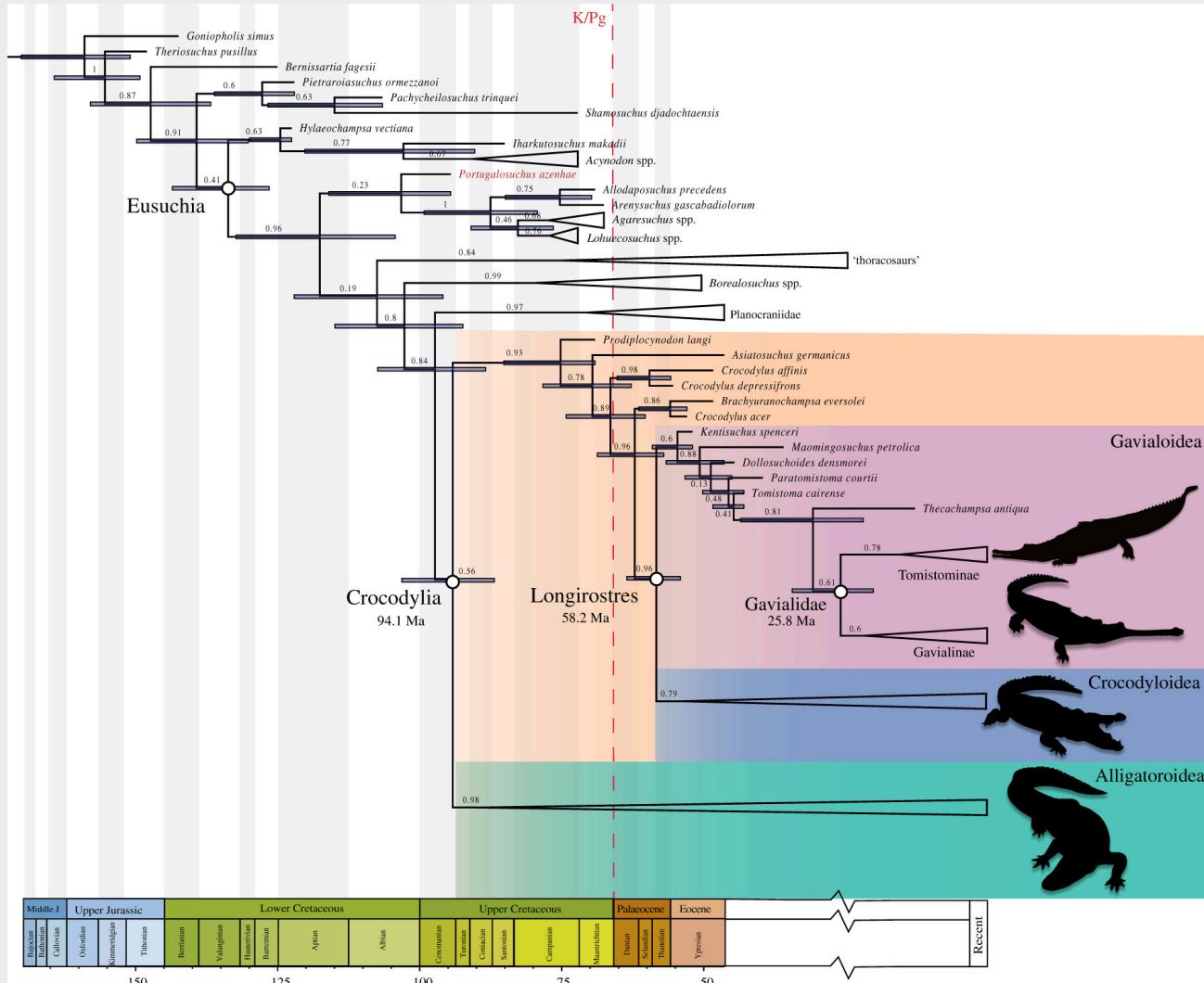
Poulakakis and Stamatakis 2010.jpg

What's the difference between a crocodile and an alligator?



Alligator: joemd; Crocodile: Wayne and Pam Osborn

So similar despite ± 95 million years of independent evolution!!!



Darlim et al 2022

Phylogeny and ecological similarity

Phylogenetic signal is the tendency for related species to resemble each other more than they resemble species drawn at random from the phylogenetic tree.

Phylogenetic niche conservatism is when closely related species are *more* similar ecologically than expected based on their relatedness (i.e. given the time they've had to diverge).

East African terns by H Douglas Pratt



Drivers of niche conservatism

I'm not going to go into detail, but conservatism may be occur through a variety of processes, including:

- lack of genetic variation for necessary traits
- genetic constraints
- developmental/morphological constraints
- selection favouring maintenance of the original niche
- competition with other species preventing divergence into other niches

What are the implications of closely related species being more similar?

The Competition-Relatedness Hypothesis

"As the species of the same genus usually have, though by no means invariably, much similarity in habits and constitution, and always in structure, the struggle will generally be more severe between them, if they come into competition with each other, than between the species of distinct genera." - Darwin 1859

In modern ecology, this translates as:

Since close relatives usually have similar traits, and thus similar niches, the limiting similarity principle dictates that they should compete more strongly than distant relatives.

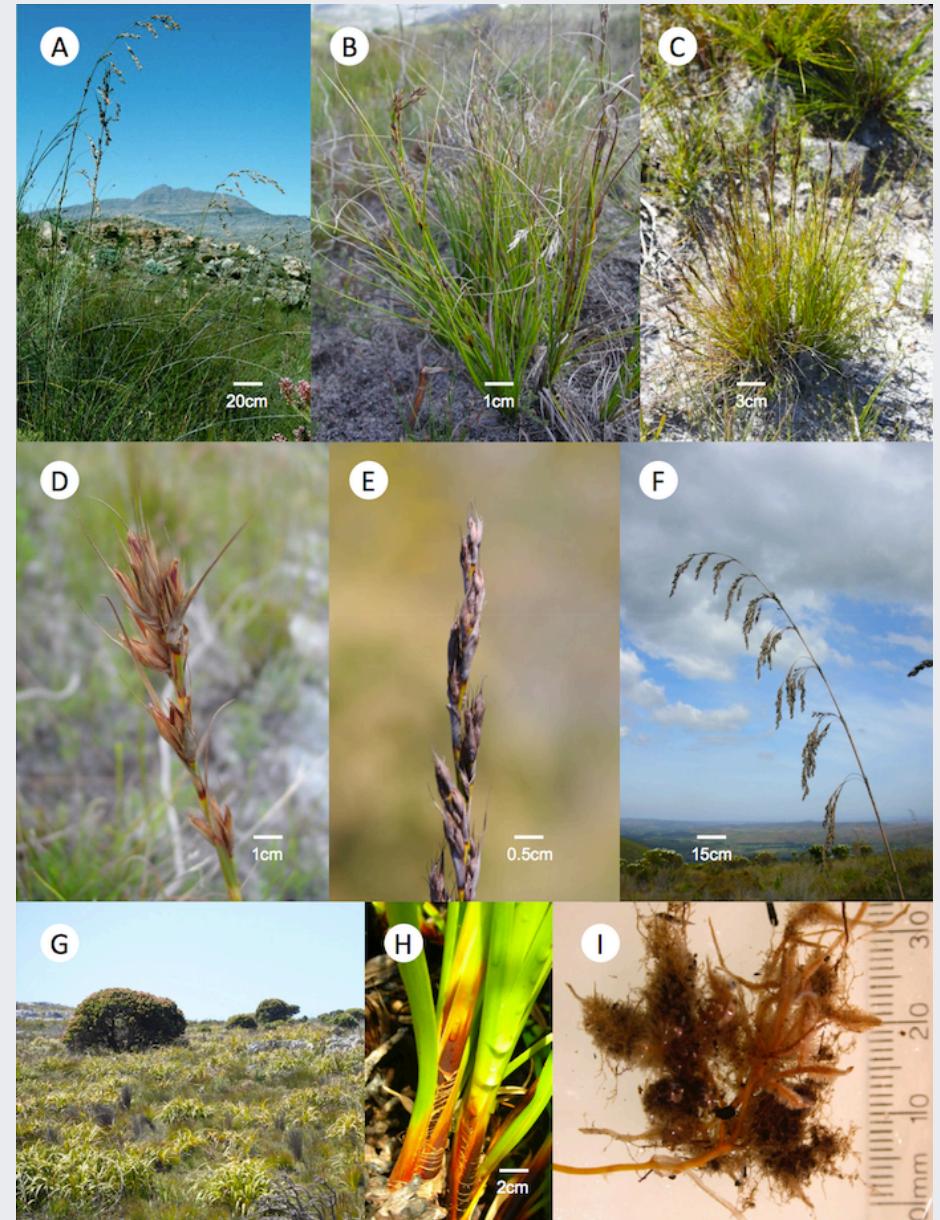
The Competition-Relatedness Hypothesis

VOL. 168, NO. 1 THE AMERICAN NATURALIST JULY 2006

Phylogenetic Relatedness Limits Co-occurrence at Fine Spatial Scales: Evidence from the Schoenoid Sedges (Cyperaceae: Schoeneae) of the Cape Floristic Region, South Africa

Jasper A. Slingsby* and G. Anthony Verboom†

Slingsby and Verboom 2006 explored patterns of co-occurrence of *Tetraria* species in plots sampled across several mountains in the CFR.

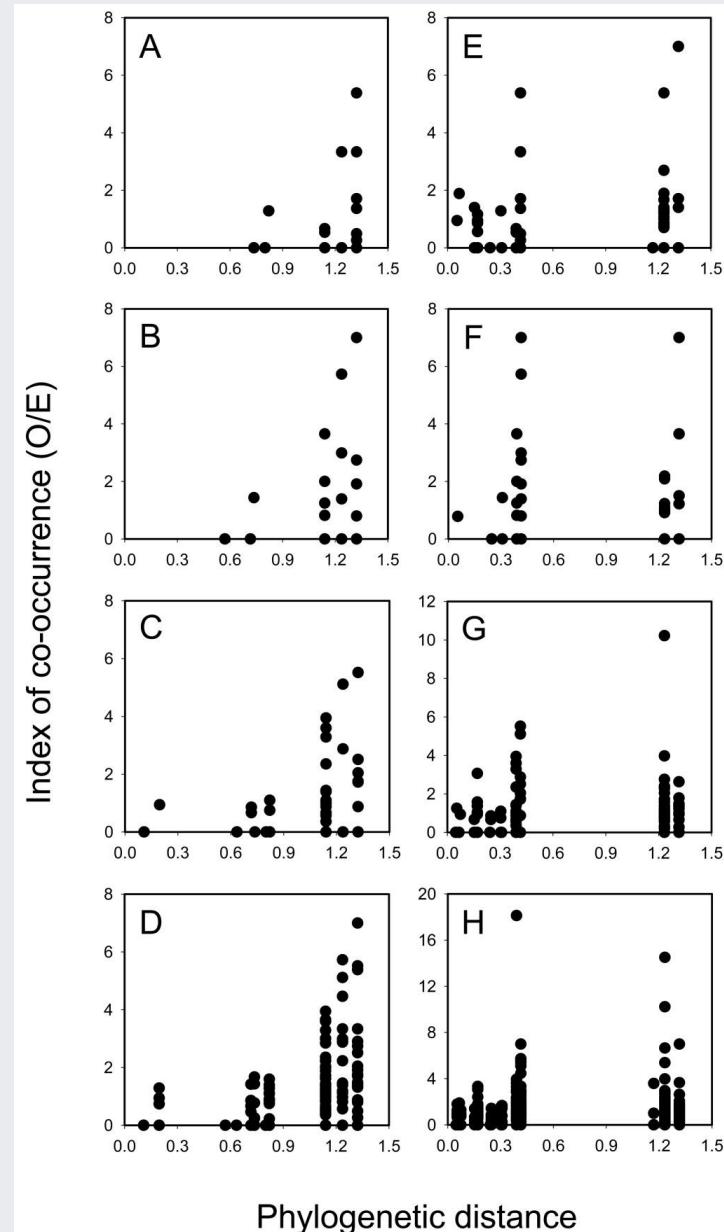


The Competition-Relatedness Hypothesis

Slingsby and Verboom 2006 explored patterns of co-occurrence of *Tetraria* species in plots sampled across several mountains in the CFR.

They found that close relatives were functionally similar (phylogenetic signal) and that they rarely co-occur (empty top-left corner of figures), as one would expect if close relatives competitively exclude one another.

Similar patterns have been found for many taxonomic groups all over the world, but it is difficult to exclude processes other than competition as potential drivers of the pattern.

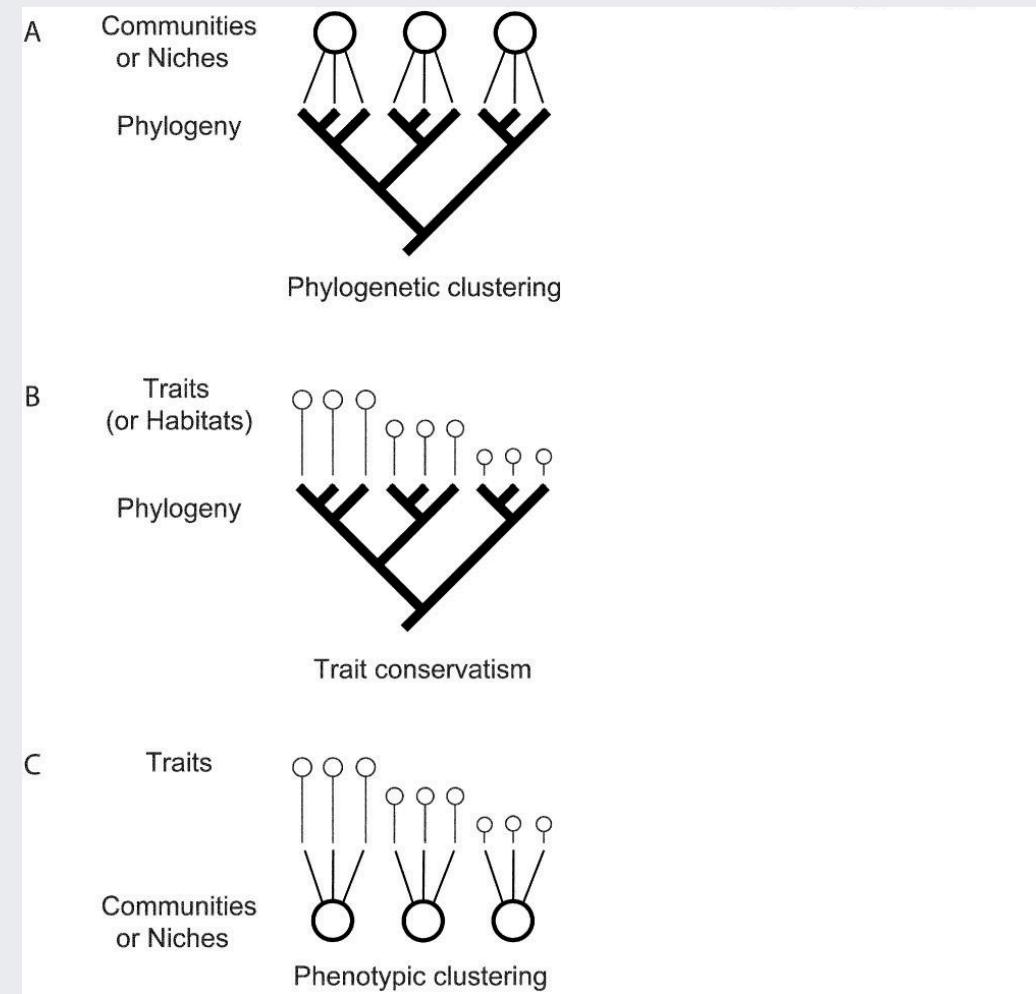
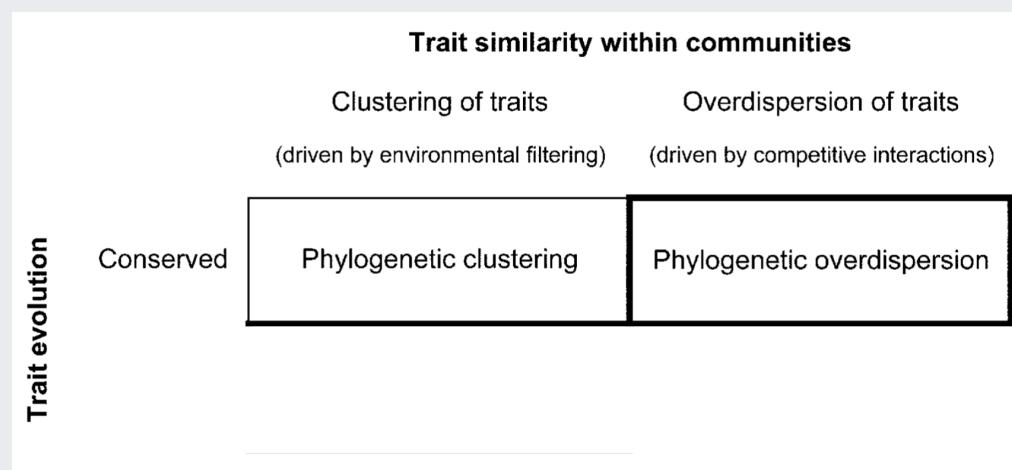


What about relatedness and habitat filtering?

Relatedness and habitat filtering

As a counter to the competition-relatedness hypothesis, since close relatives should have similar traits and niches, you might expect them to be filtered into the same communities.

This sets up contrasting predictions, depending on whether competition or habitat filtering are the dominant processes...



Cavender-Bares et al. 2004

Relatedness and habitat filtering

Ecological Monographs, 80(3), 2010, pp. 401–422
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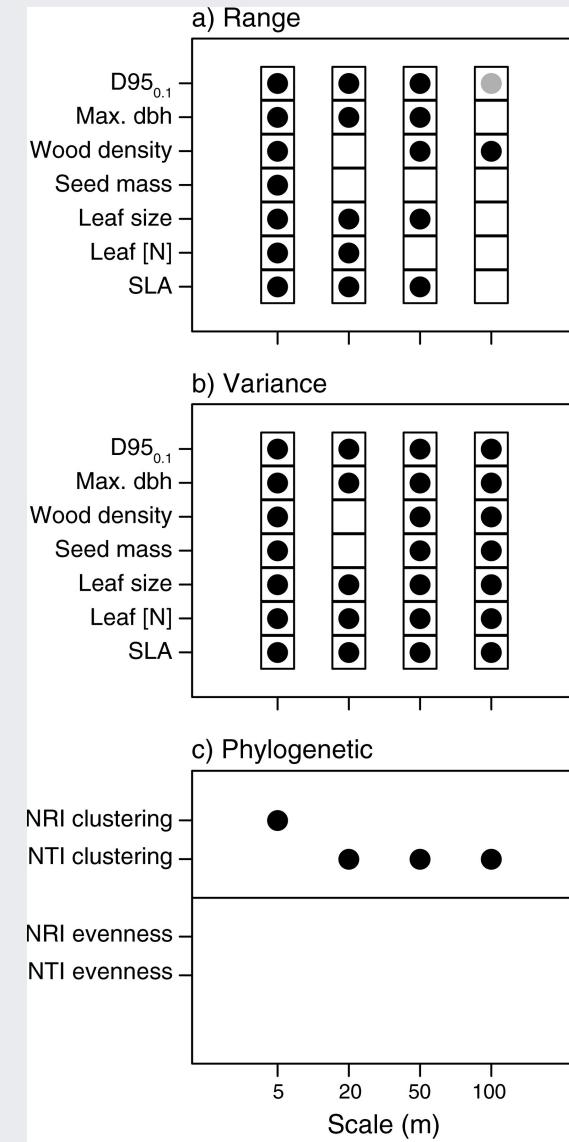
Functional trait and phylogenetic tests of community assembly across spatial scales in an Amazonian forest

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Revisiting our rainforest example from the previous lecture, **Kraft and Ackerly 2010** did a follow-up study looking at trait conservatism and phylogenetic relatedness in their forest plot.

They found that the range and variance of a set of key traits were smaller than expected by chance (i.e. clustered), and that the communities showed phylogenetic clustering at a range of plot sized from 5 to 100m.



Relatedness and habitat filtering

Journal of
Ecology 2007
95, 1316–1323

Fire drives phylogenetic clustering in Mediterranean Basin woody plant communities

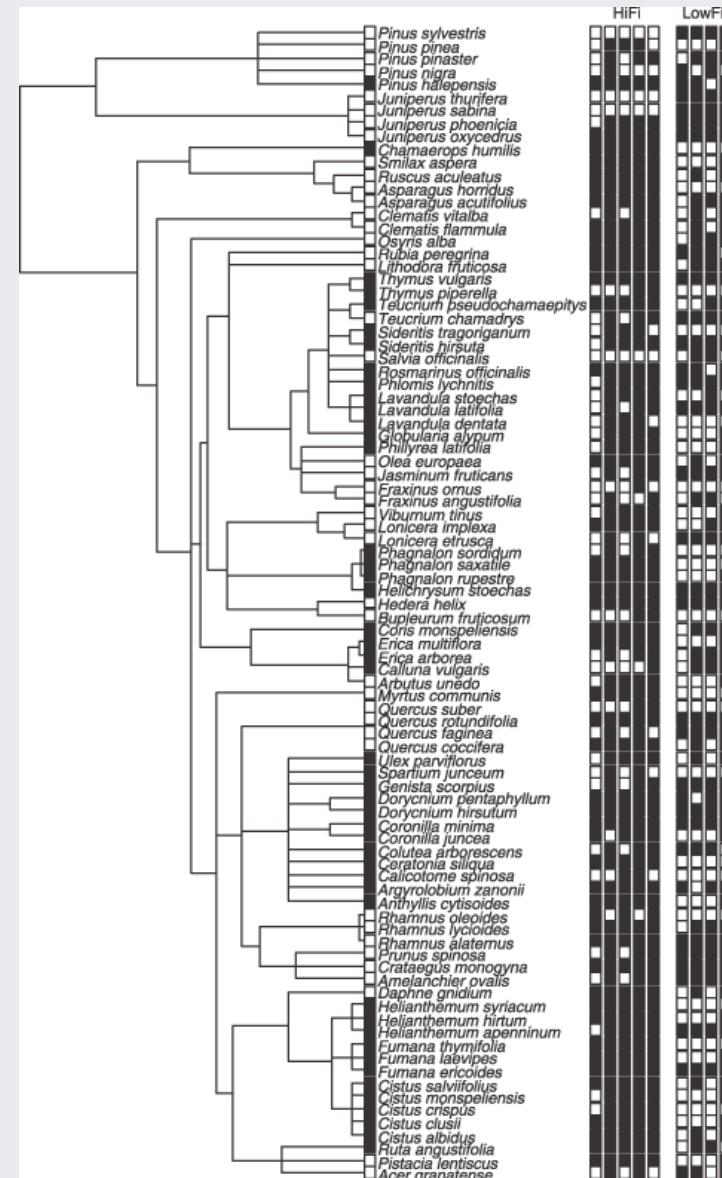
M. VERDÚ* and J. G. PAUSAS†

*Centro de Investigaciones sobre Desertificación (CIDE, CSIC-UV), Camí de la Marjal s/n Apartado Oficial, 46470 Albal, València, Spain, and †Centro de Estudios Ambientales del Mediterráneo (CEAM), C/Charles R. Darwin 14, Parc Tecnològic, 46980 Paterna, València, Spain, and Department of Ecology, University of Alacant, Alacant, Spain

Mediterranean plant species persist after fire by having hard-coated seeds or serotinous cones to protect them from the heat of the fire and permit rapid post-fire recruitment.

Verdu and Pausas 2007 tested and showed:

1. seed traits show phylogenetic signal
2. co-occurring species have similar seed/cone phenotypes (phenotypic clustering)
3. communities in high fire frequency environments (HiFi) are significantly phylogenetically clustered



Relatedness and habitat filtering

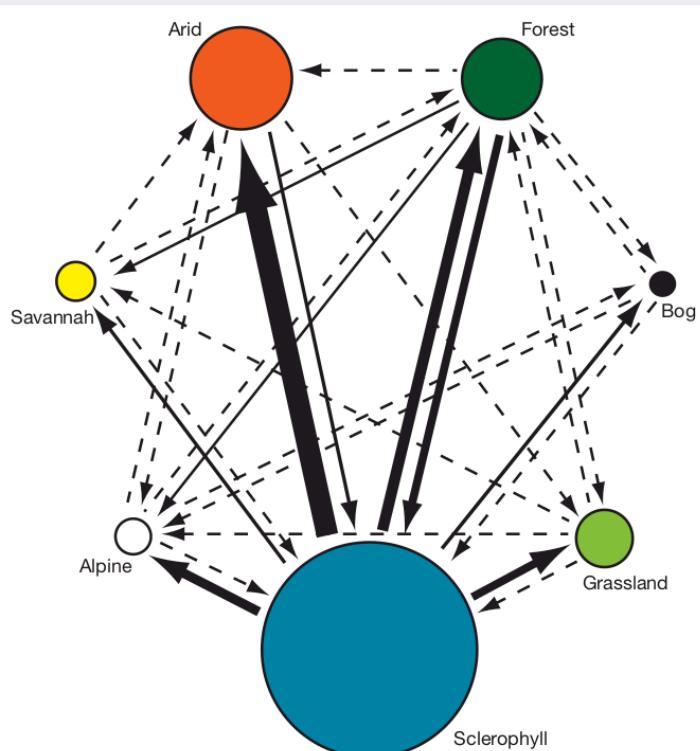


Figure 1 | Biome shifts within landmasses. Shifts occurred with only 356 of 10,800 speciation events within landmasses. Number of species sampled within each biome is proportional to the area of each circle: sclerophyll, 7,250; arid, 1,683; wet forest, 1,005; temperate grassland, 504; savannah, 242; montane, 186; bog, 84. Arrow thickness is proportional to the number of transitions in each direction, ranging from 6 to 95 events; dashed lines indicate 1–5 events and lack of an arrow indicates that there was no event.

Niche conservatism and global biogeography!

Table 1 | Biome transitions coincident with transoceanic colonizations

Destination	Source							
	Arid	Bog	Forest	Grassland	Sclerophyll	Alpine	Savannah	Total
Arid	2							
Bog		13.3						3.3
Forest			50.8					10
Grassland				21.7				6.3
Sclerophyll	1	0.3	3.5	2.7	87		1	8.5
Alpine			1	2	7	12		10
Savannah				1		0.5		1.5
Total	1	0.3	5.5	4.7	26.1	1	1	39.6

The number of biome transitions is shown for each biome in terms of source (columns) and sink (rows). Bold numbers along the diagonal show colonizations with no change of biome. Totals are for transitions only, that is, excluding values along the diagonal. Non-integer values result from fractional weighting of ambiguous reconstructions. For clarity, zeroes are left blank.

Speciation is more likely to occur via dispersal to a similar biome on a different continent than to a different biome right next door!

It's Easier to Move Than to Evolve (Unless It Isn't)

These studies suggest what may be a general principle, namely that under many circumstances it may be easier for species to migrate into an area with at least some of the relevant adaptations having already evolved, than it is for those adaptations to evolve in place. This formulation highlights two key variables, namely the rate of trait evolution in relation to the rate of dispersal. But, the existence of relevant geographic/climatic

Figures: Crisp et al. 2009; Quote: Donoghue 2008

But what if the key traits/niche are not conserved?

Divergence in traits and/or niches is relatively common, as we see in adaptive radiations such as the Honeycreepers of the Hawaiian archipelago.

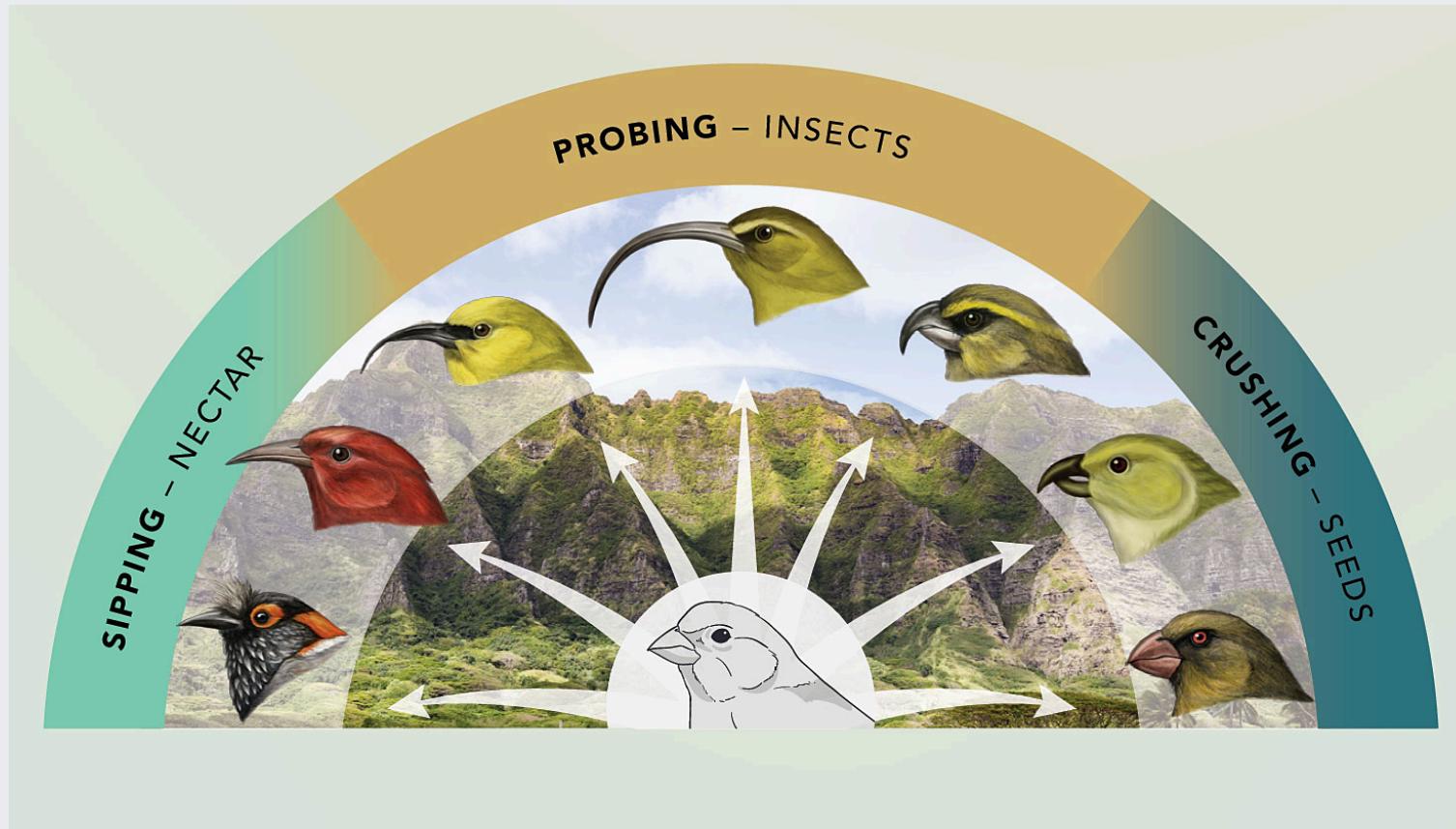


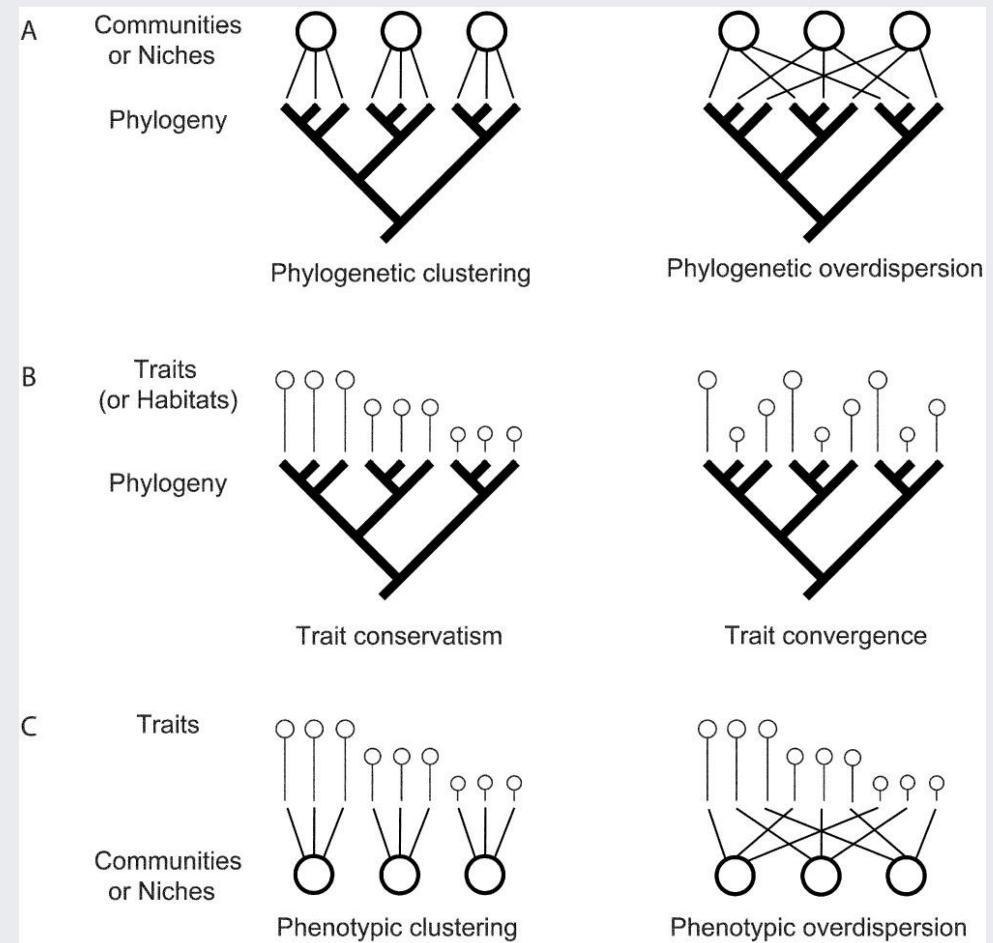
Illustration by Jillian Ditner, photo by Ashlyn Gehrett

Relatedness and habitat filtering

If we consider that close relatives may not have similar traits and niches, you might expect them to be filtered into different communities.

In fact, one can have distant relatives *converge* to the same traits or niche preferences (**convergent evolution**), leading to habitat filtering selecting for communities of distantly related species!

Trait similarity within communities		
	Clustering of traits (driven by environmental filtering)	Overdispersion of traits (driven by competitive interactions)
Conserved	Phylogenetic clustering	Phylogenetic overdispersion
Convergent	Phylogenetic overdispersion	Phylogenetic clustering or random dispersion

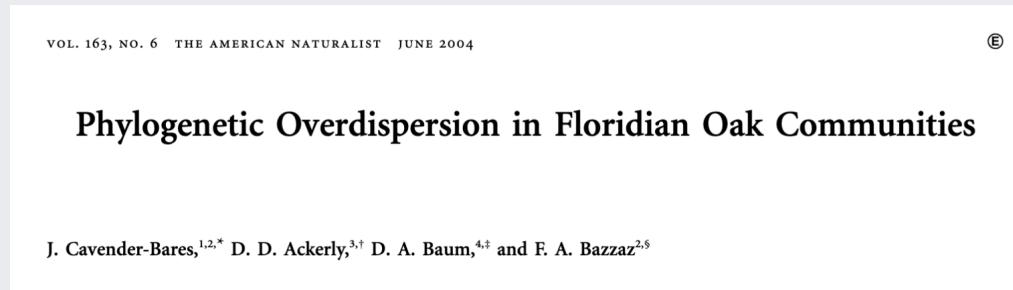


Note that there are no clear predictions for competition and convergent evolution...

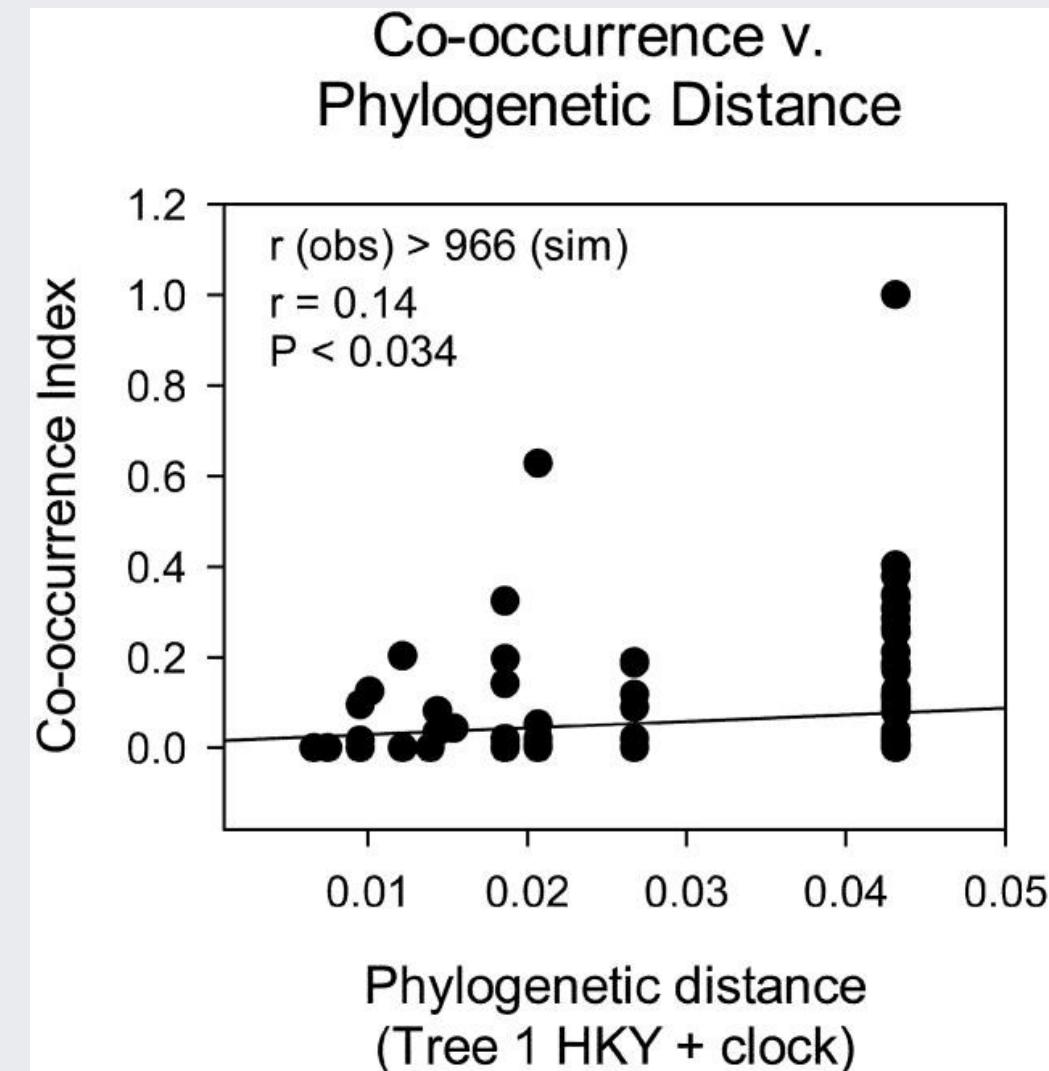
Cavender-Bares et al. 2004

Relatedness and habitat filtering

Habitat filtering and *convergent evolution*



A similar pattern to Slingsby and Verboom 2006!



Cavender-Bares et al. 2004

Relatedness and habitat filtering

Habitat filtering and *convergent* evolution

VOL. 163, NO. 6 THE AMERICAN NATURALIST JUNE 2004

Phylogenetic Overdispersion in Floridian Oak Communities

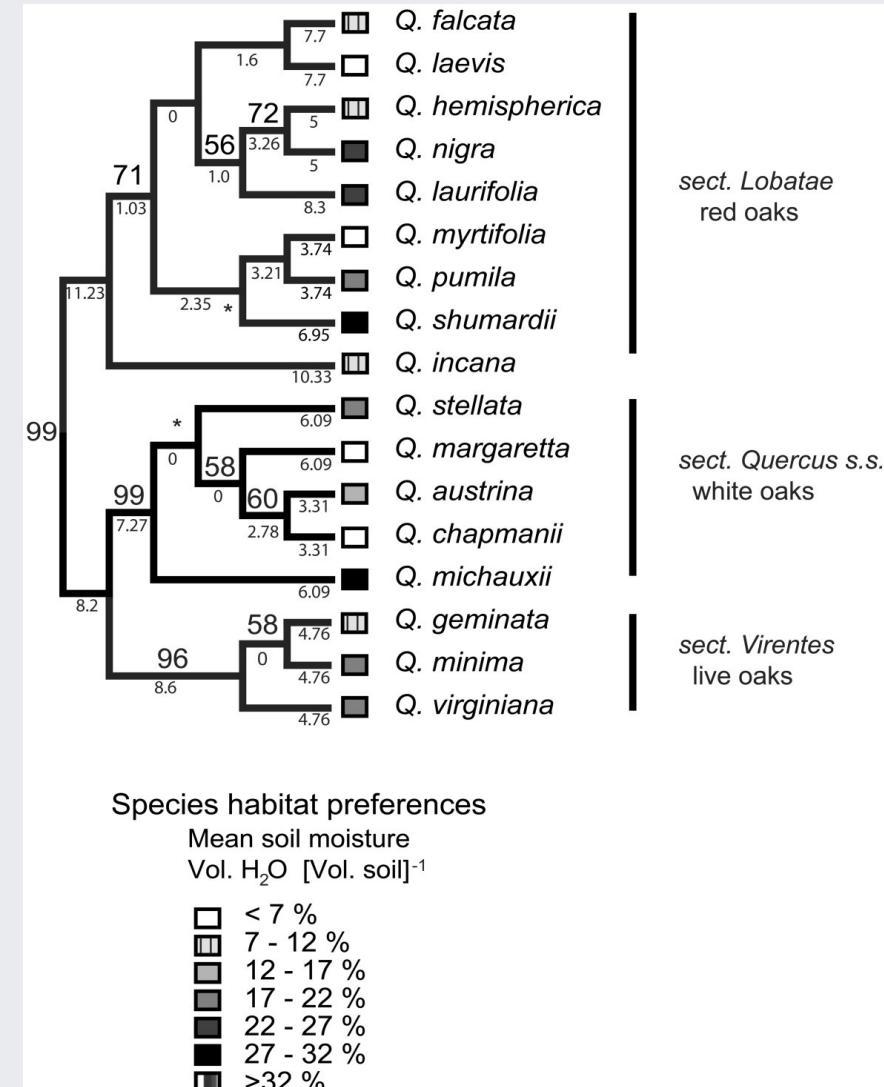
J. Cavender-Bares,^{1,2,*} D. D. Ackerly,^{3,†} D. A. Baum,^{4,‡} and F. A. Bazzaz²

A similar pattern to Slingsby and Verboom 2006!

But

This pattern was driven by convergent evolution of niches!

To discern between processes, you have to test for phylogenetic signal.



Cavender-Bares et al. 2004

Niches and Diversification

Since niches are key for the distribution and coexistence of species, it stands to reason that they should feed back to affect the diversification process?

THE EVOLUTION OF MORPHOLOGICAL DIVERSITY

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KEY WORDS: ecomorphology, evolutionary radiation, extinction, macroevolution, theoretical morphology

One proposal is that diversification should slow through time as niche space is gradually filled. This is termed density- (or diversity-) dependent diversification.

The idea has its roots in paleobiology, based on the fossil record, but has since been explored using molecular phylogenies.

Foote 1997

Diversity-dependent diversification



Proc. R. Soc. B (2008) 275, 2363–2371
doi:10.1098/rspb.2008.0630
Published online 8 July 2008

Density-dependent diversification in North American wood warblers

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The key notion is that the diversification rate declines through time as the number of lineages increases (and presumably niche space saturates).

While the notion that there is an ecological limit on diversification is a somewhat controversial one, there's enough evidence of a pattern that it cannot be ignored, even if we're not sure of the process. We may yet find alternative explanations...

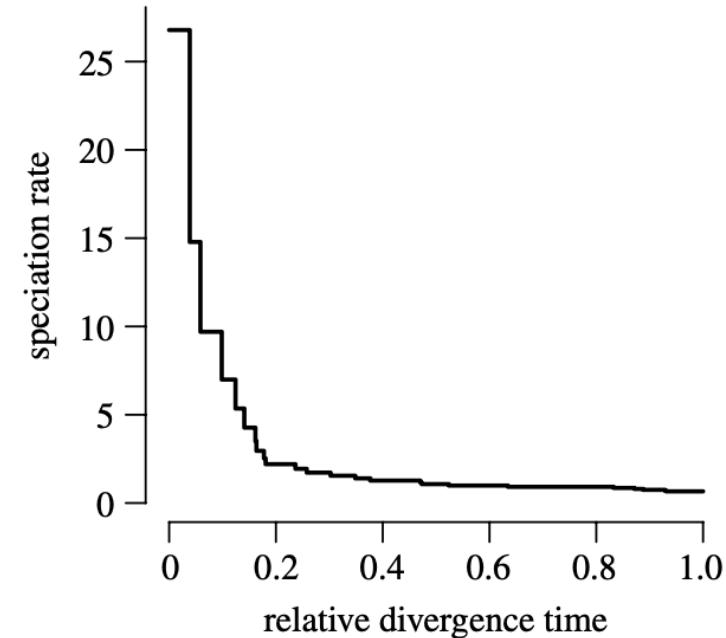


Figure 3. Maximum-likelihood reconstruction of speciation-through-time curve under overall best-fit model (density-dependent exponential). Rates are given in lineages per time unit assuming that the basal divergence occurred 1.0 time units before the present.

Rabosky and Lovette 2008

Diversity-dependent diversification

Ecology limits the diversity of the Cape flora: Phylogenetics and diversification of the genus *Tetraria*

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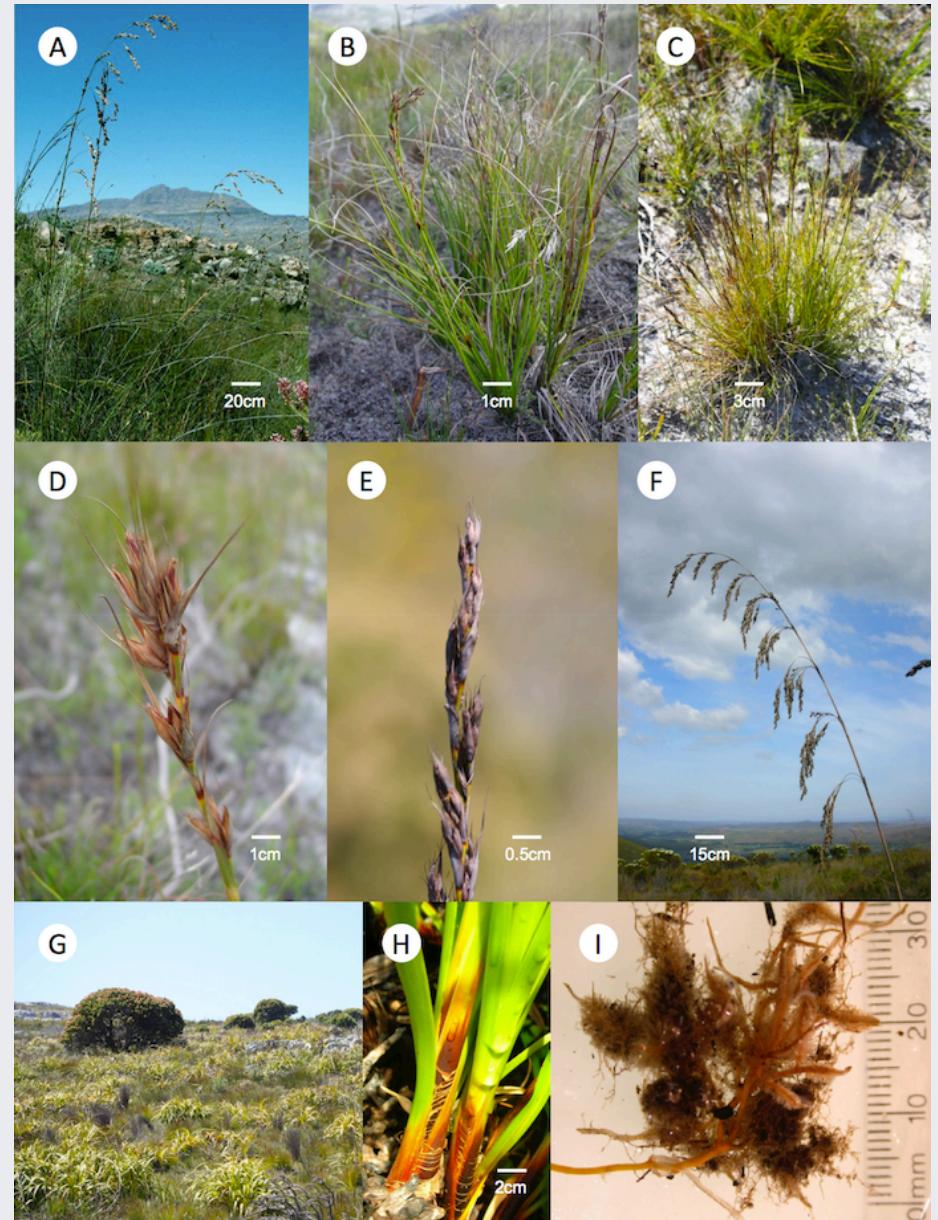
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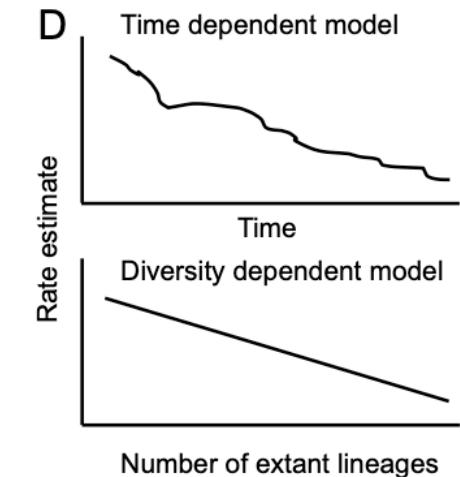
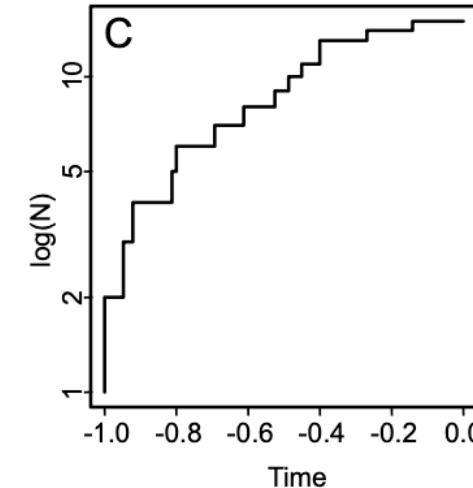
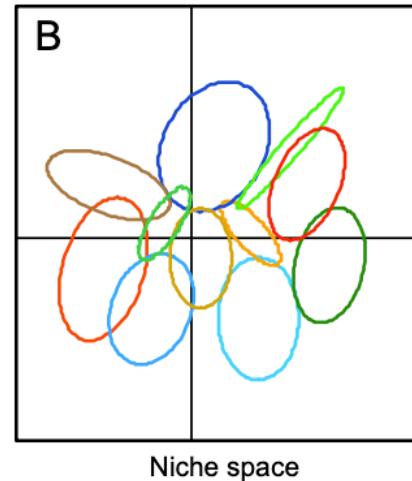
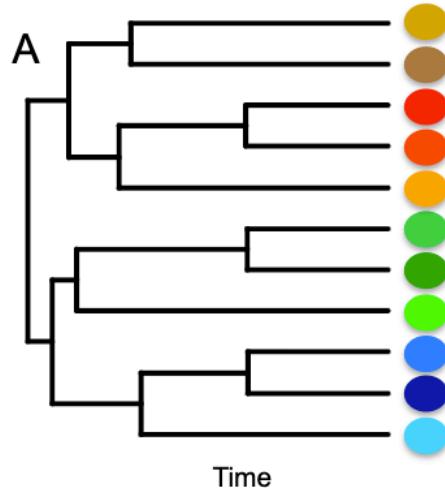
There's even some evidence for it from the Cape...

Revisiting the genus *Tetraria*...

Slingsby et al. 2013



Diversity-dependent diversification



The rate of speciation (bifurcation of the phylogeny (A)) declines as niche space (B) is progressively filled. This creates a signal of declining rates of diversification through time (C), but is better fit by a model whereby diversification rate is a function of the number of extant lineages (D), implying an ecological limit on diversification. If this is a common phenomenon in lineages in the Cape it has major significance for our understanding of the diversity, distribution and dynamics of the contemporary flora.

Take-home

Phylogenetic relatedness can have a profound effect on the similarity of species' niches, with the expectation being that species should show phylogenetic signal (close relatives are more similar than distant relatives).

Under some circumstances, one may even have phylogenetic niche conservatism, where close relatives are more similar than you'd expect on the basis of phylogenetic signal alone.

In other cases, one can have trait or niche convergence, where distant species evolve similar traits/niches (e.g. sharks and dolphins).

The nature of trait/niche evolution has implications for the patterns of relatedness on biotic communities under different ecological processes (competition vs habitat filtering).

Niche conservatism can also have a big impact on global biogeography in that it seems to be easier for species to disperse between continents than to shift between biomes.

There is even some evidence that niche evolution can affect the rate of diversification, with rates slowing as more species accumulate and niche space saturates. This is often considered to be an ecological limit on diversification.

Thanks!

Slides created via the R packages:

xaringan
gadenbuie/xaringanthemer

The chakra comes from remark.js, **knitr**, and R Markdown.