New phylogenetic methods for detecting, understanding, and conserving centers of endemism

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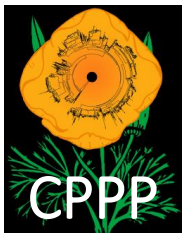
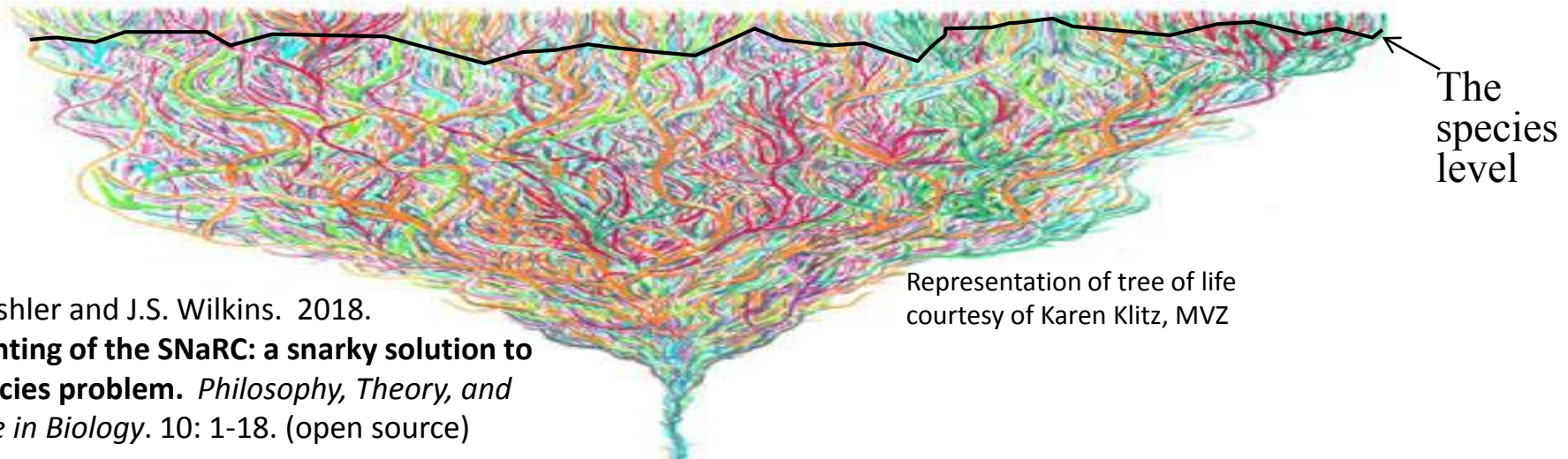
With thanks to my collaborators in the California Plant Phylodiversity Project: Matt Kling, Andrew Thornhill, Bruce Baldwin, and David Ackerly.



Biodiversity is not just species

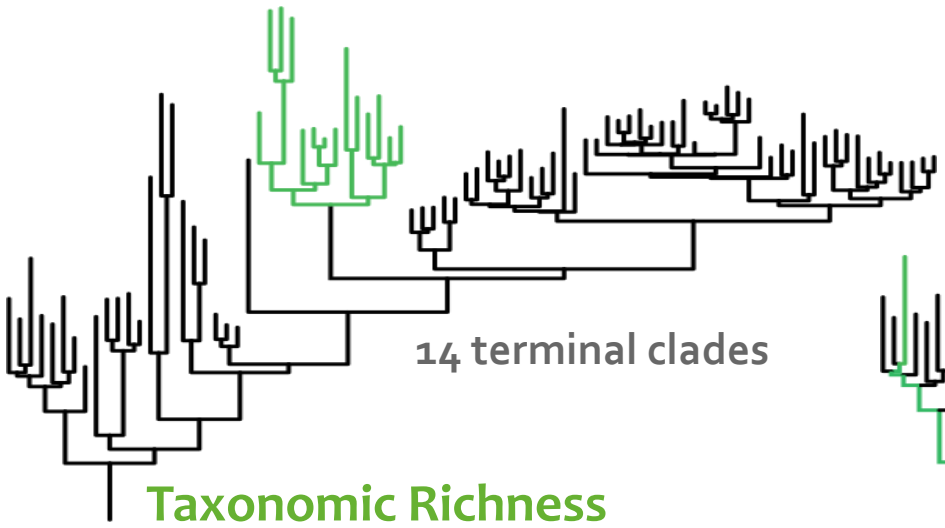
- Biodiversity is the *whole tree of life*, not just named species.
- There are lineages smaller and larger than the traditional species level.
- Species are not comparable among lineages, they are at best just an arbitrary cut-off somewhere along a branch in the tree of life.
- Likewise, endemism is not just about species, even though virtually all studies on endemism to the present focus solely on species. Clades at all levels can be endemic to a greater or lesser extent, and all levels are relevant to discovery and evaluation of centers of endemism.
- Thus for a true understanding of diversity and endemism, *we need to look at the whole tree*.

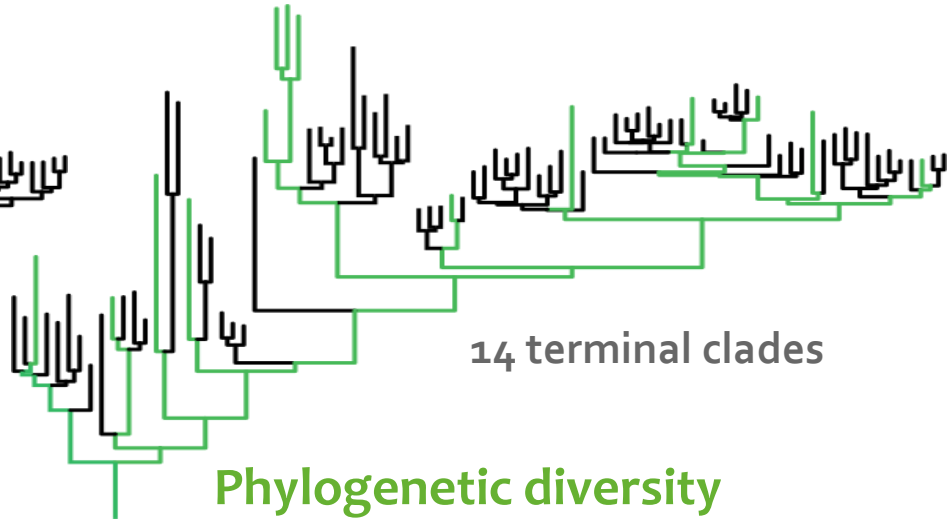


Representation of tree of life courtesy of Karen Klitz, MVZ

B.D. Mishler and J.S. Wilkins. 2018. **The hunting of the SNaRC: a snarky solution to the species problem.** *Philosophy, Theory, and Practice in Biology*. 10: 1-18. (open source)

Measuring biodiversity & endemism





- Traditional metrics: species richness and weighted endemism (inverse of range size)
- Alternative metrics: **phylogenetic diversity** (PD) and **phylogenetic endemism** (a PD measure, but with each branch divided by its range size)

Spatial phylogenetics → *Placing the tree of life on maps*

Investigations on species alone lacks the depth of a phylogenetic approach.

Spatial Phylogenetics combines two main elements, a phylogeny and a spatial dataset representing phylogeny terminals.

Can be applied at any taxonomic and geographic level.

Measures diversity and endemism based on branch length and phylogenetic relatedness.

Because the approach is rank free it doesn't matter what taxonomic levels the terminals represent, as long as they are monophyletic.

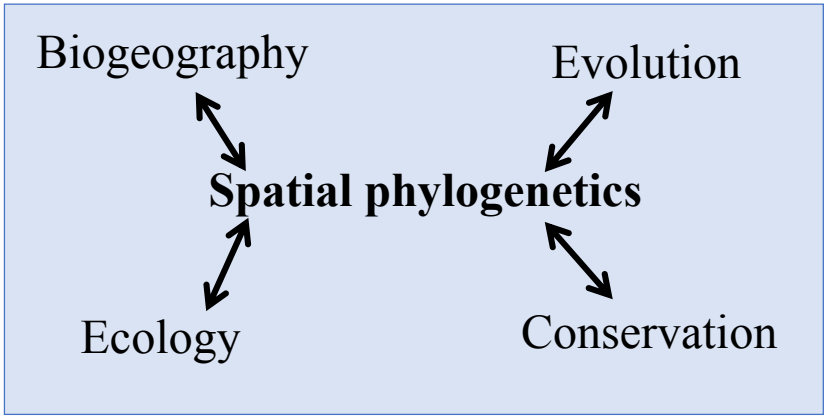
Relatively robust to lumping and splitting decisions.

A "big data" approach enabled by technological advances:

Advances in digitization and availability of natural history museums specimens

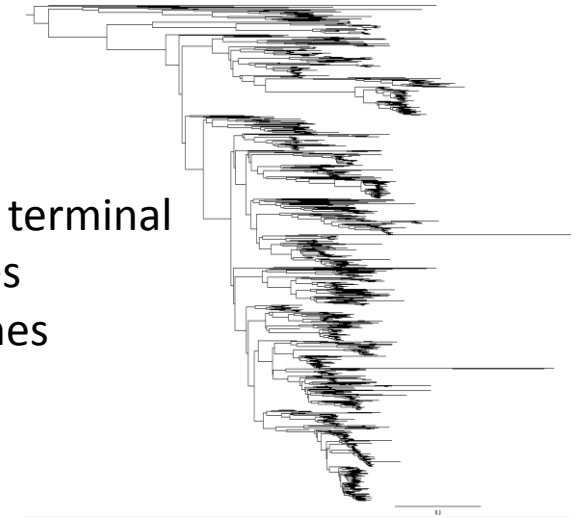
Plethora of DNA in GenBank; advances in mining software.

Major advances in computational methods for both tree-building and tree-using e.g. RAxML



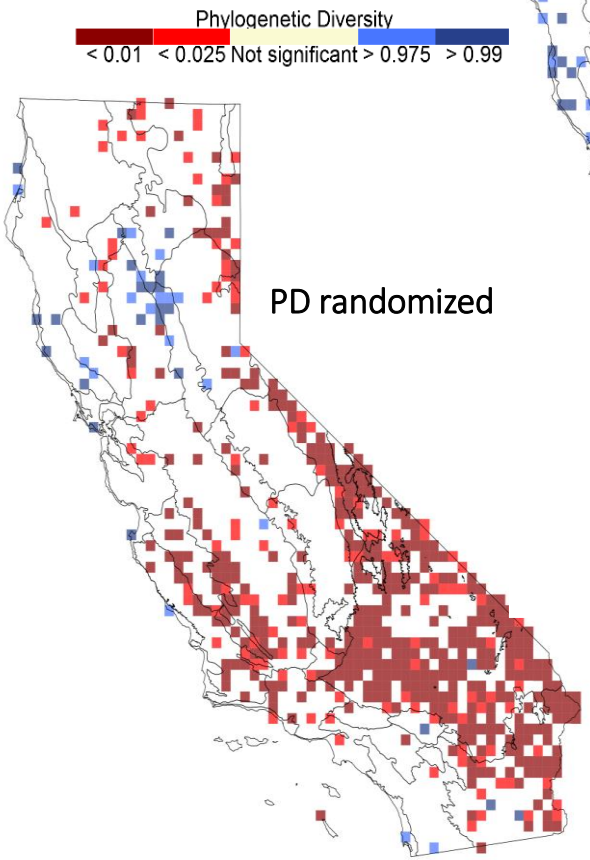
Quick review of:

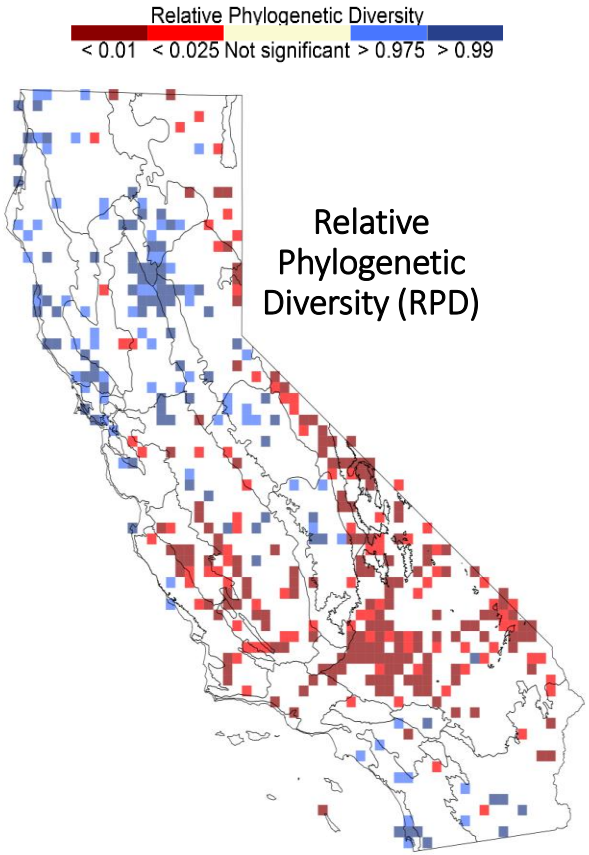
A.H. Thornhill, B.G. Baldwin, W.A. Freyman, S. Nosratinia, M.M. Kling, N. Morueta-Holme, T.P Madsen, D.D. Ackerly, and B.D. Mishler. 2017. **Spatial phylogenetics of the native California flora**. *BMC Biology* 15:96.

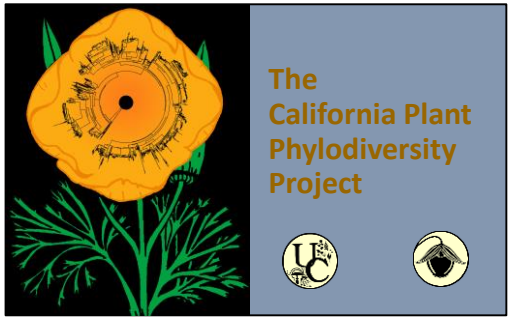


1083 terminal clades
9 genes

1.4 million herbarium specimen records after cleaning – all datasets deposited online







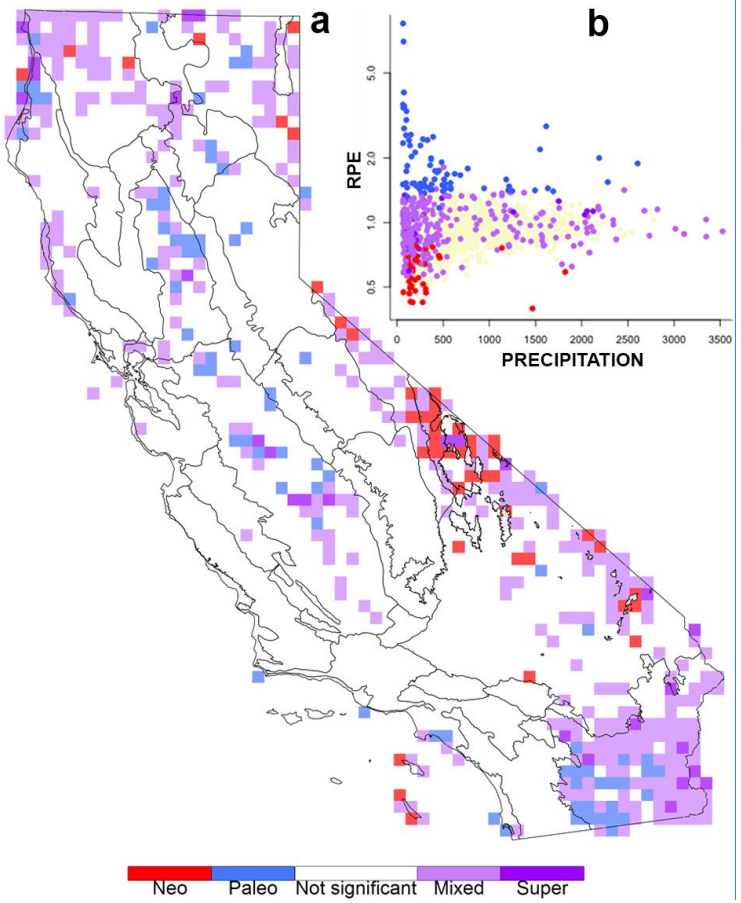
We test statistical significance using spatial randomizations of the terminal taxa on the map, subject to two constraints: richness of each grid cell and range size of each taxon remains constant.

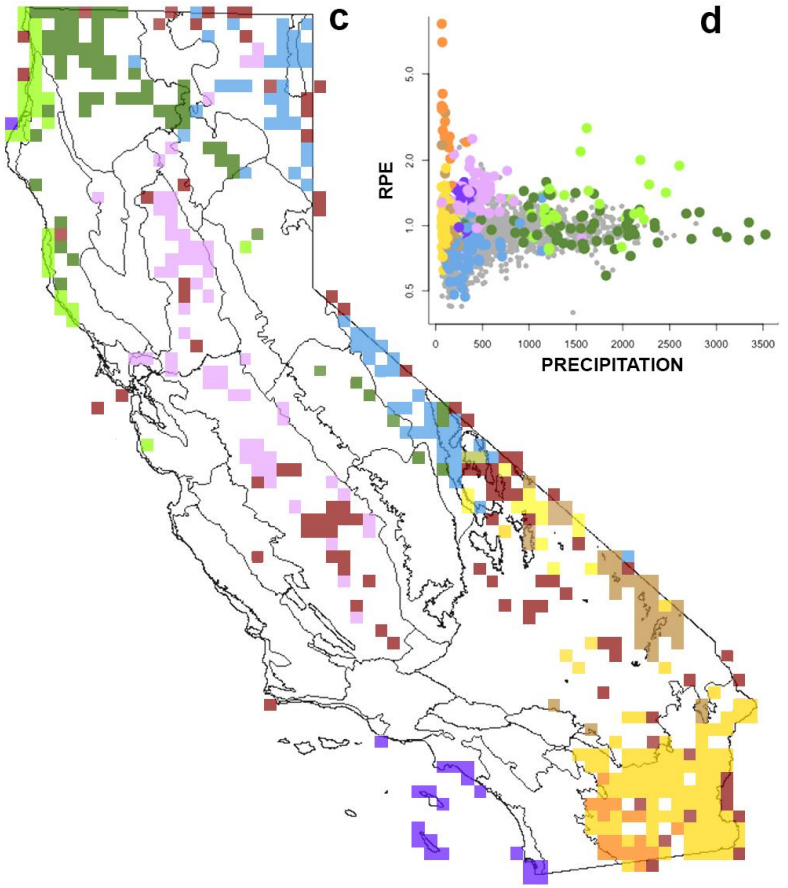
CANAPE: Categorical Analysis of Neo- And Paleo-Endemism

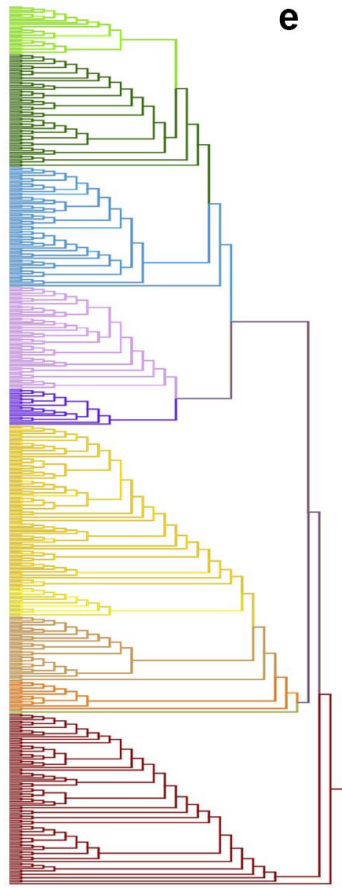
RPE - *relative phylogenetic endemism* = $\frac{\text{PE on the range-weighted original tree}}{\text{PE on a range-weighted comparison tree with all branch lengths equal}}$

Blue = centers of paleoendemism
Red = centers of neoendemism
Purple = centers of mixed endemism

Beta-diversity:
Phyloturnover among centers of endemism.
Here colors indicate similarity among grid cells



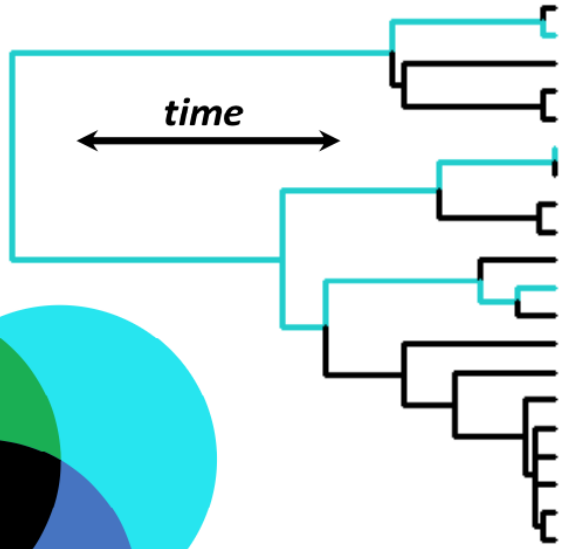


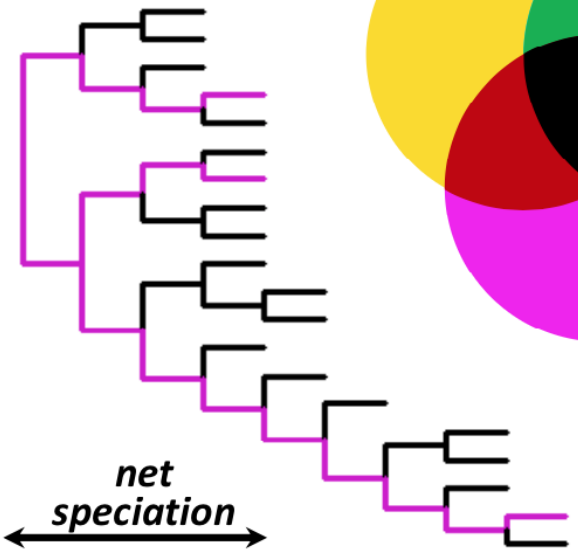


The three facets of phylodiversity

DIVERGENCE:
high PD on phylogram =
disparate assemblages

SURVIVAL TIME:
high PD on chronogram =
experienced assemblages





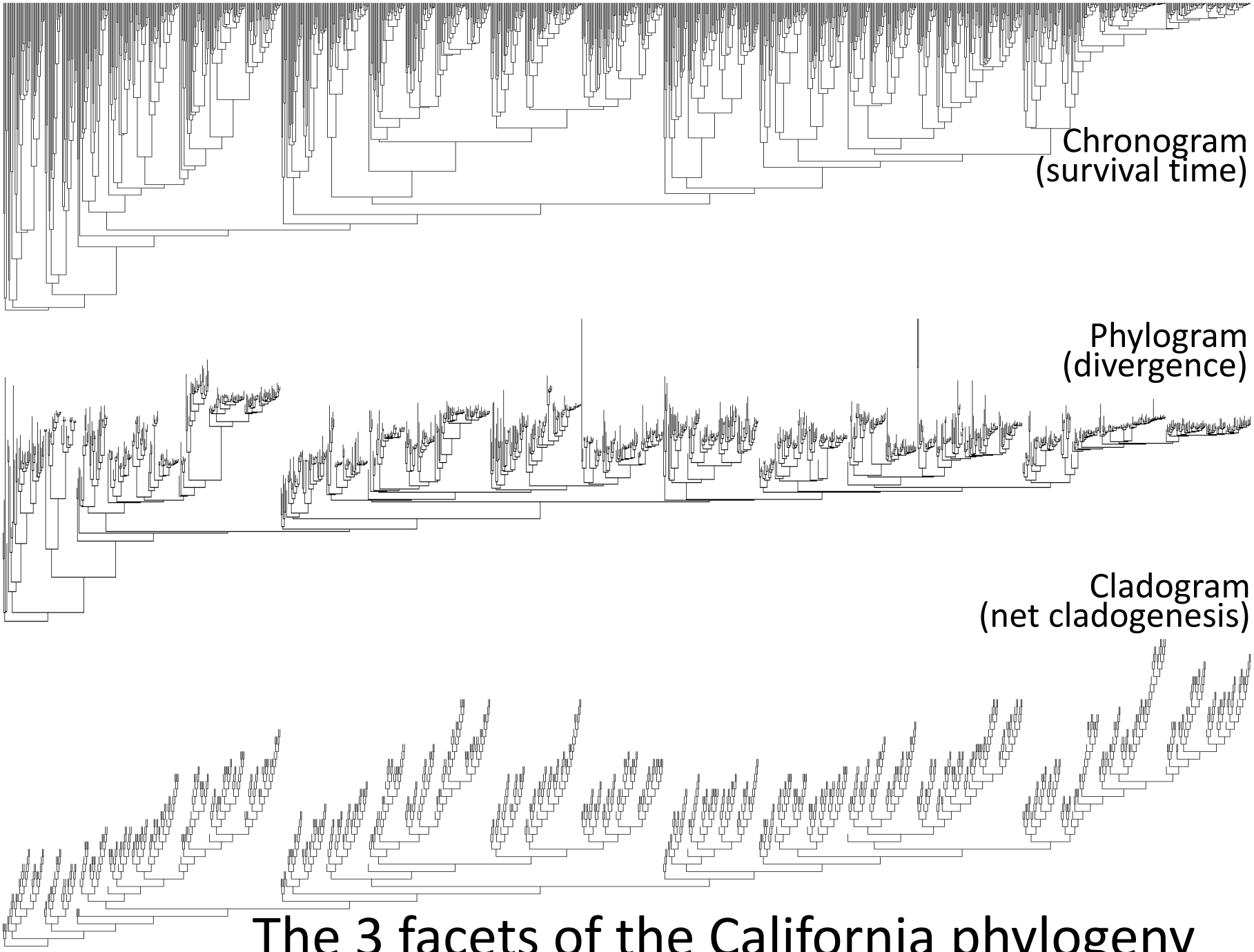
NET DIVERSIFICATION:
high PD on cladogram =
assemblages from
species-rich clades

Now change focus from locations of hotspots of diversity and endemism in general.

Start from where we are at moment in land protection in California and decide what to do next.

From: M.M. Kling, B.D. Mishler, A.H. Thornhill, B.G. Baldwin, and D.D. Ackerly. 2018. **Facets of phylodiversity: evolutionary diversification, divergence, and survival as conservation targets.** *Philosophical Transactions Royal Society B.* 374: 20170397

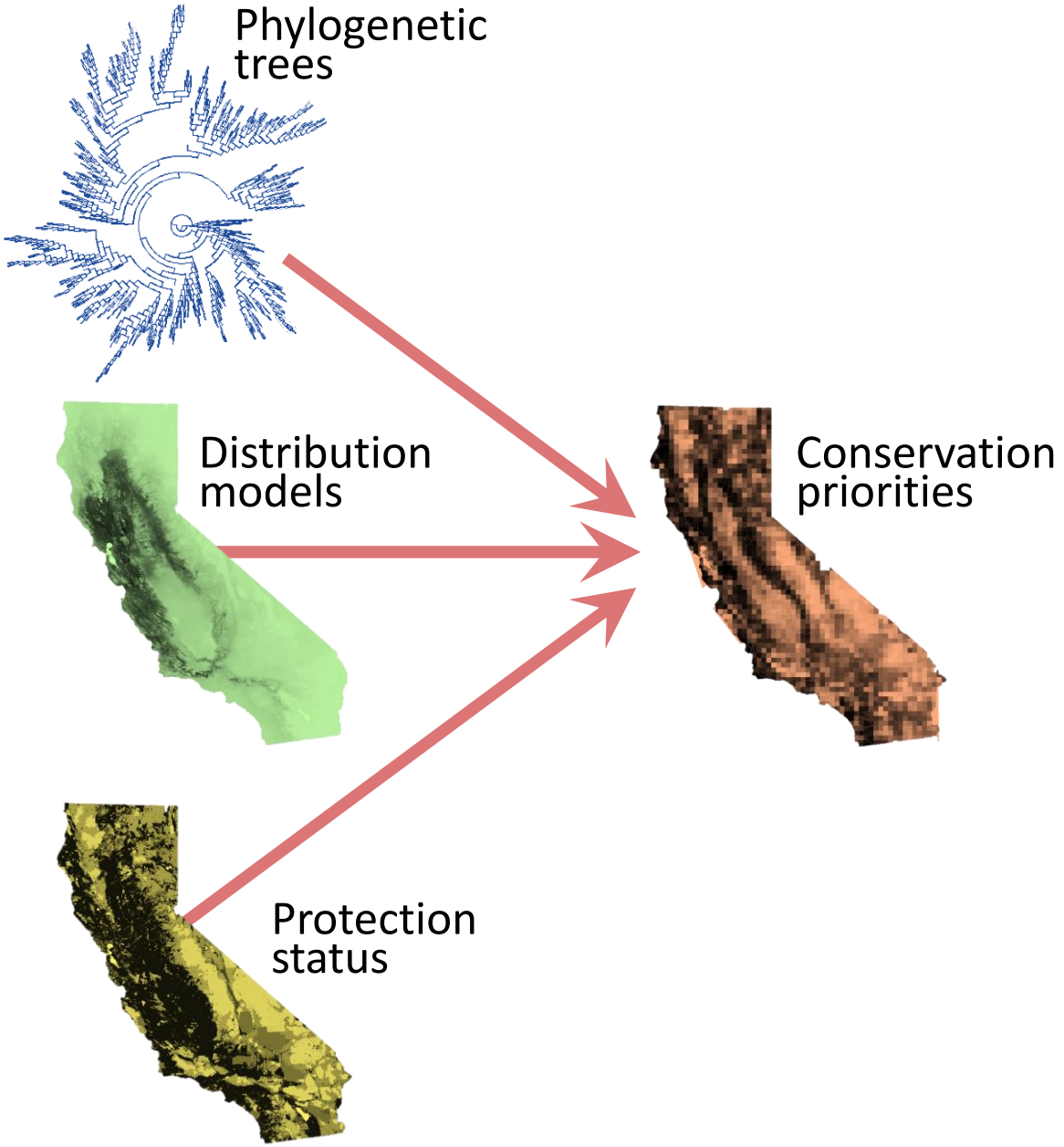
The California Plant Phylodiversity Project

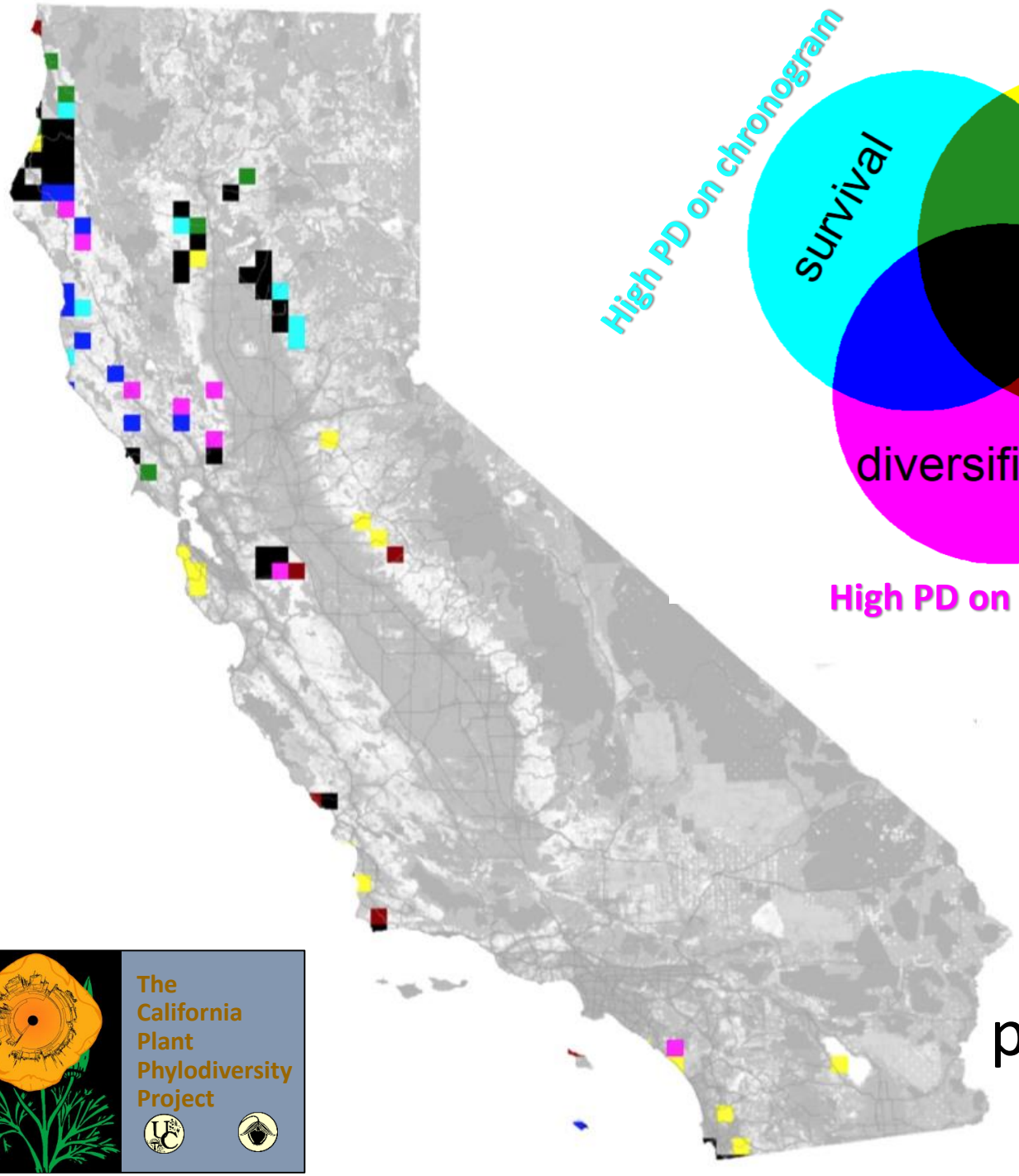


The 3 facets of the California phylogeny

Optimal conservation targets:

- Poor protection
- High intactness
- High biodiversity value, i.e, many resident taxa with:
  - Long branches
  - Small ranges
  - Poor protection across ranges





The California Plant Phylodiversity Project

Top 50 conservation priorities for each of the 3 facets

An app is available on the UC/JEPS website to explore the results in real time!

See: http://ucjeps.berkeley.edu/phylodiversity/