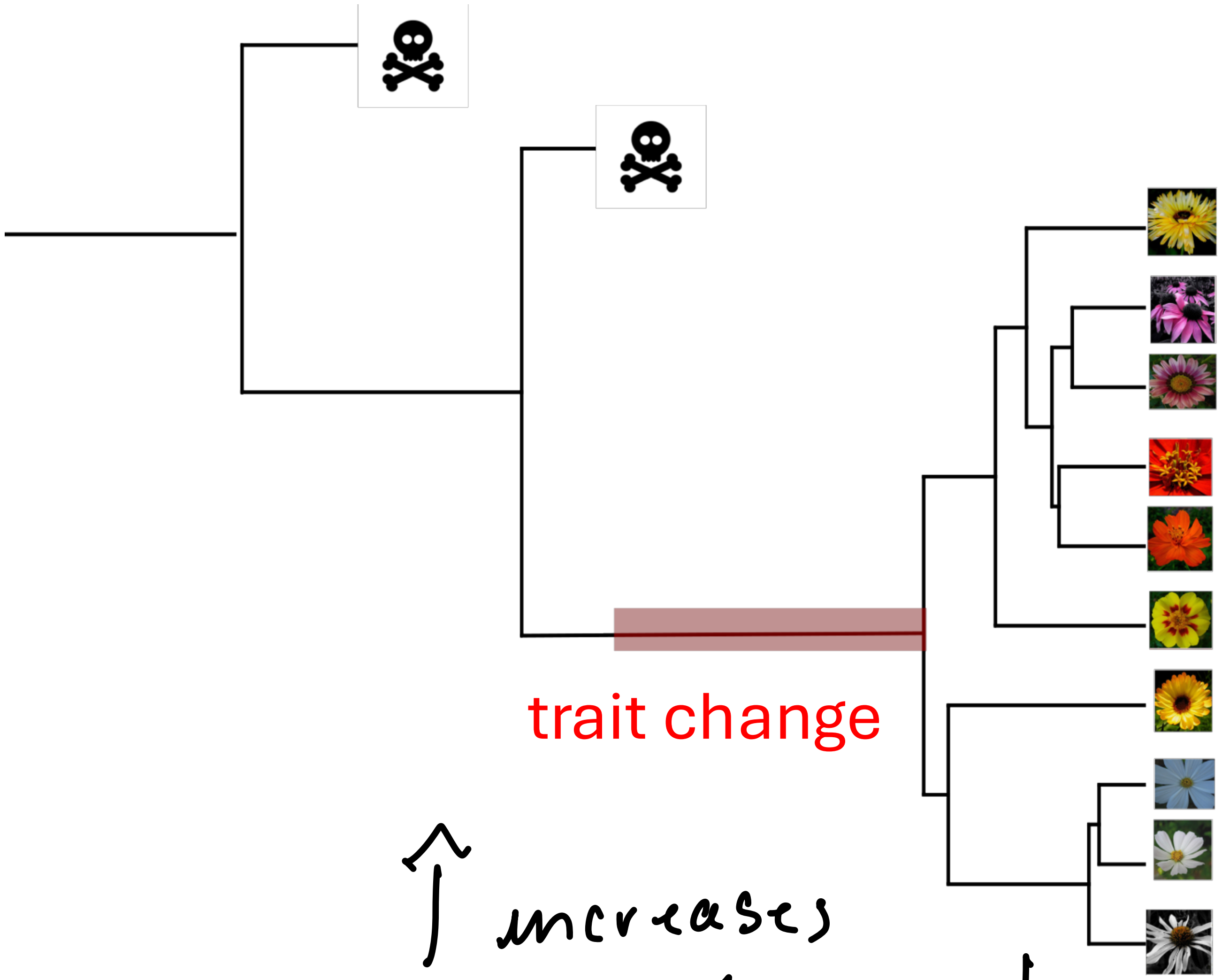
State-dependent diversification models

Introduction to phylogenetic comparative methods

BIO508- Rosana Zenil-Ferguson

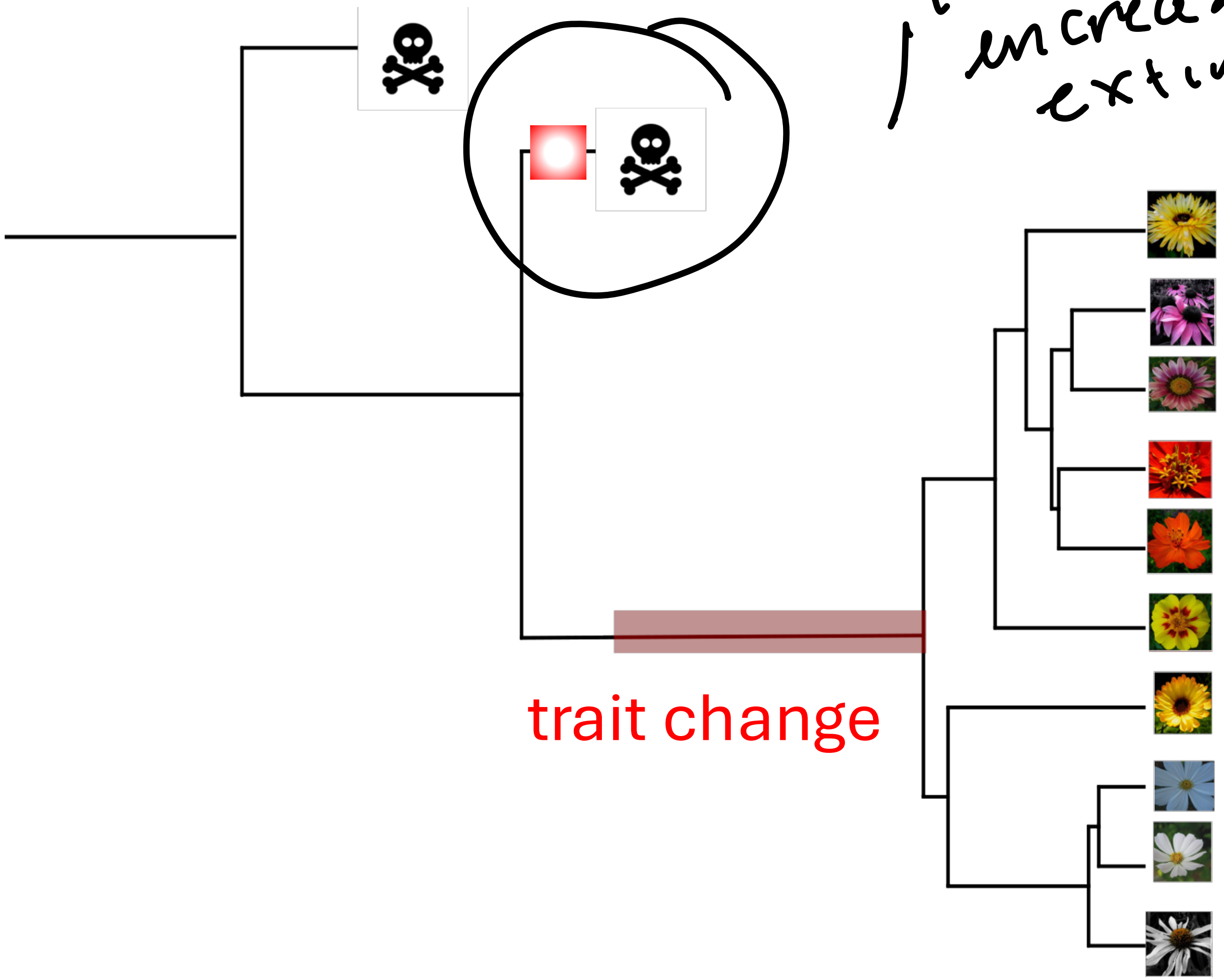
Macroevolutionary consequences of trait change



↑ increases speciation

↓ decreases extinction

Macroevolutionary consequences of trait change



↑ increases extinction

↓ decreases speciation

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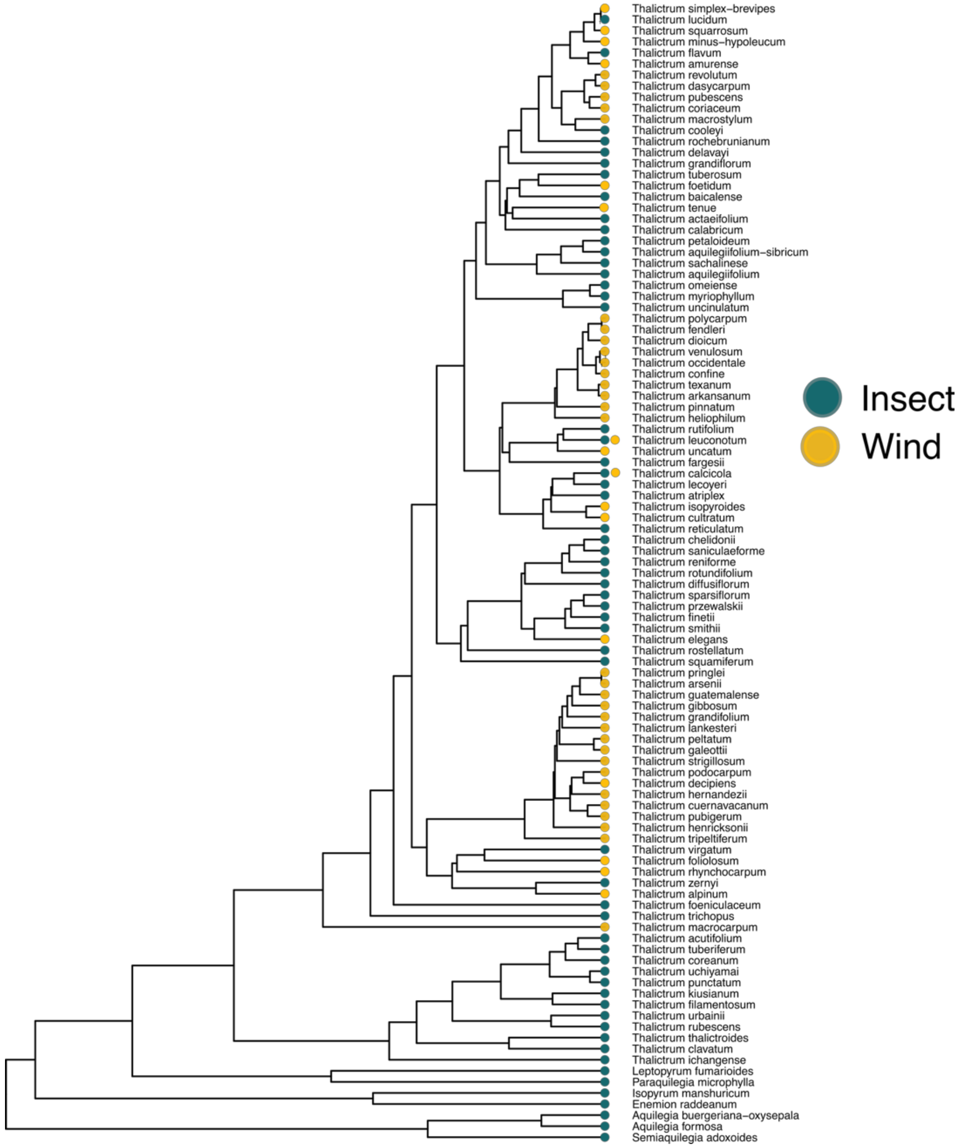
Perspective

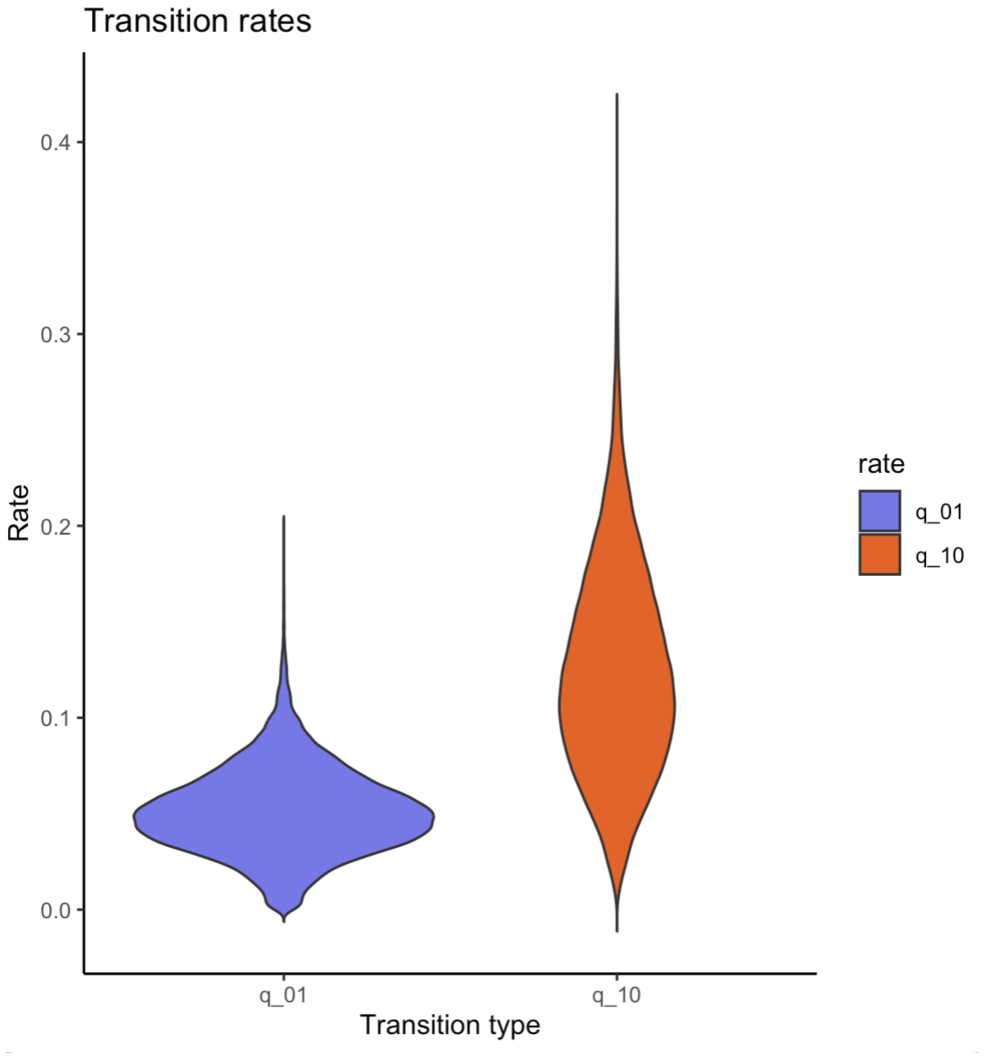
Opposing effects of plant traits on diversification

Bruce Anderson,[1,*] John Pannell,[2] Sylvain Billiard,[3] Concetta Burgarella,[4] Hugo de Boer,[5] Mathilde Dufay,[6] Andrew J. Helmstetter,[7] Marcos Méndez,[8] Sarah P. Otto,[9] Denis Roze,[10] Hervé Sauquet,[11,12] Daniel Schoen,[13] Jürg Schönenberger,[14] Mario Vallejo-Marin,[15] Rosana Zenil-Ferguson,[16] Jos Käfer,[17,*] and Sylvain Glémin[15,18,*]

Polyploidy	↑	↑	↓	↑
	Gene redundancy allows evolution of new functions and facilitates divergence.	*Divergent resolution of gene redundancy leads to post-zygotic incompatibilities.*	*Instability in meiosis and minority cytotype disadvantage leads to mating difficulties*	*Gene redundancy buffers deleterious mutations and allows evolution of new functions, which increases adaptive potential in changing environments.*

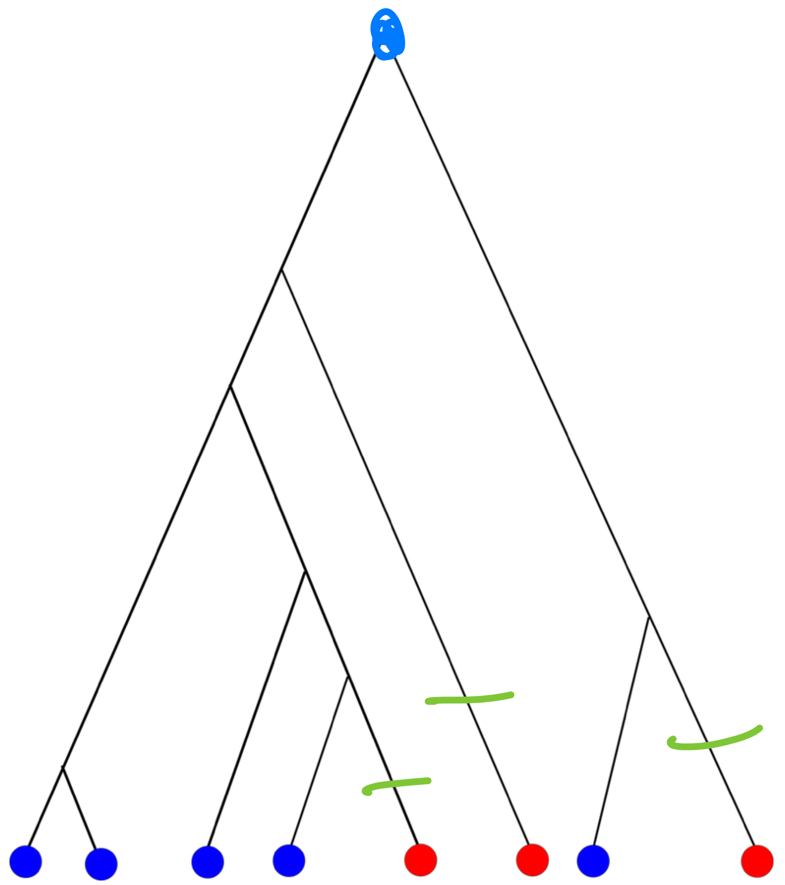
Under a Mk2 we estimated for our data



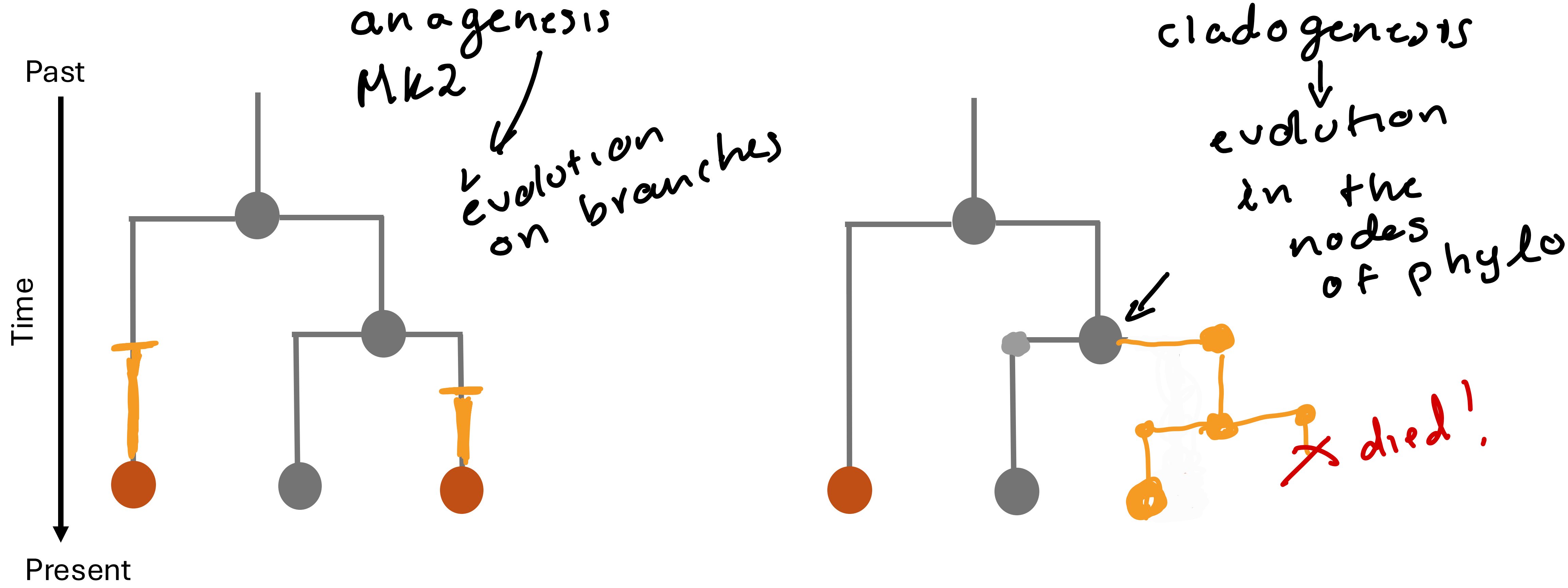


Stop and think

Where and how many transitions happened in this phylogeny?



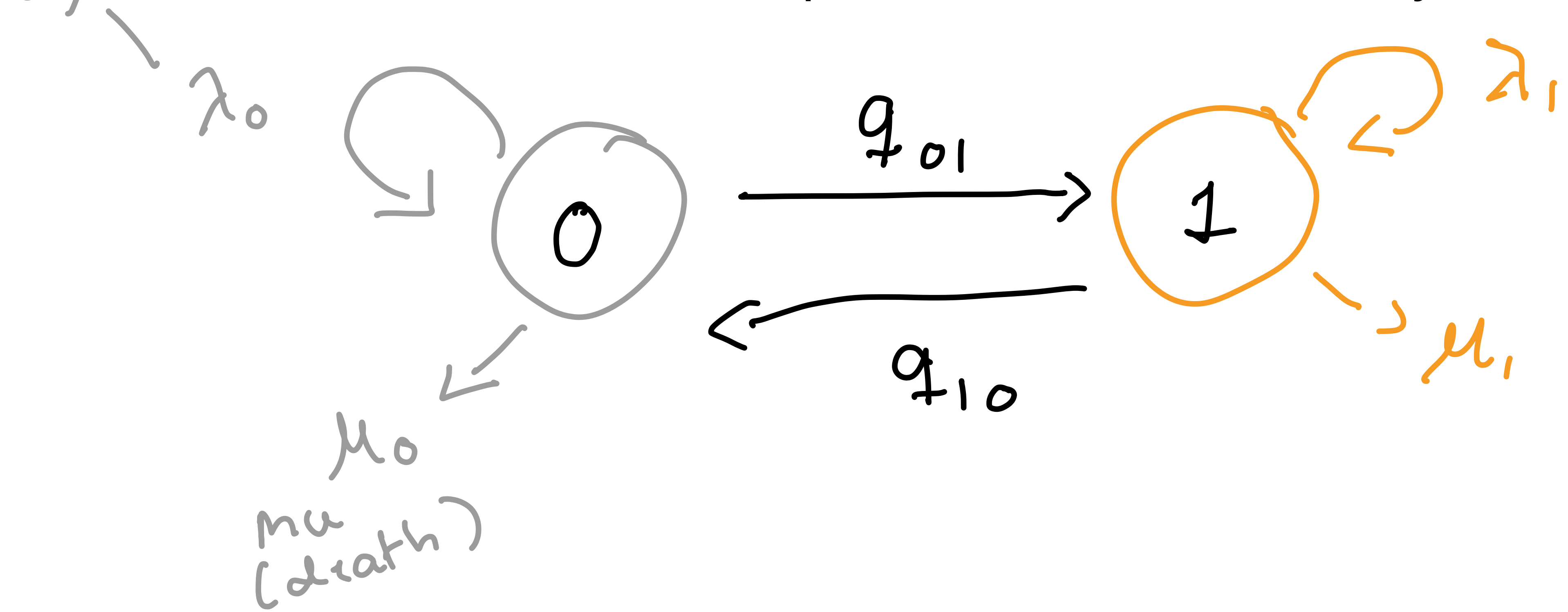
Trait evolution is biased without understanding the role of speciation and extinction events



Maddison. 2006. *Sys Bio.*

Considering speciation and extinction is necessary to decrease biases in ancestral reconstruction and estimates of transition rates

¿How do we model state dependent diversification?
Two birth and death processes connected by transitions



SCAN ME

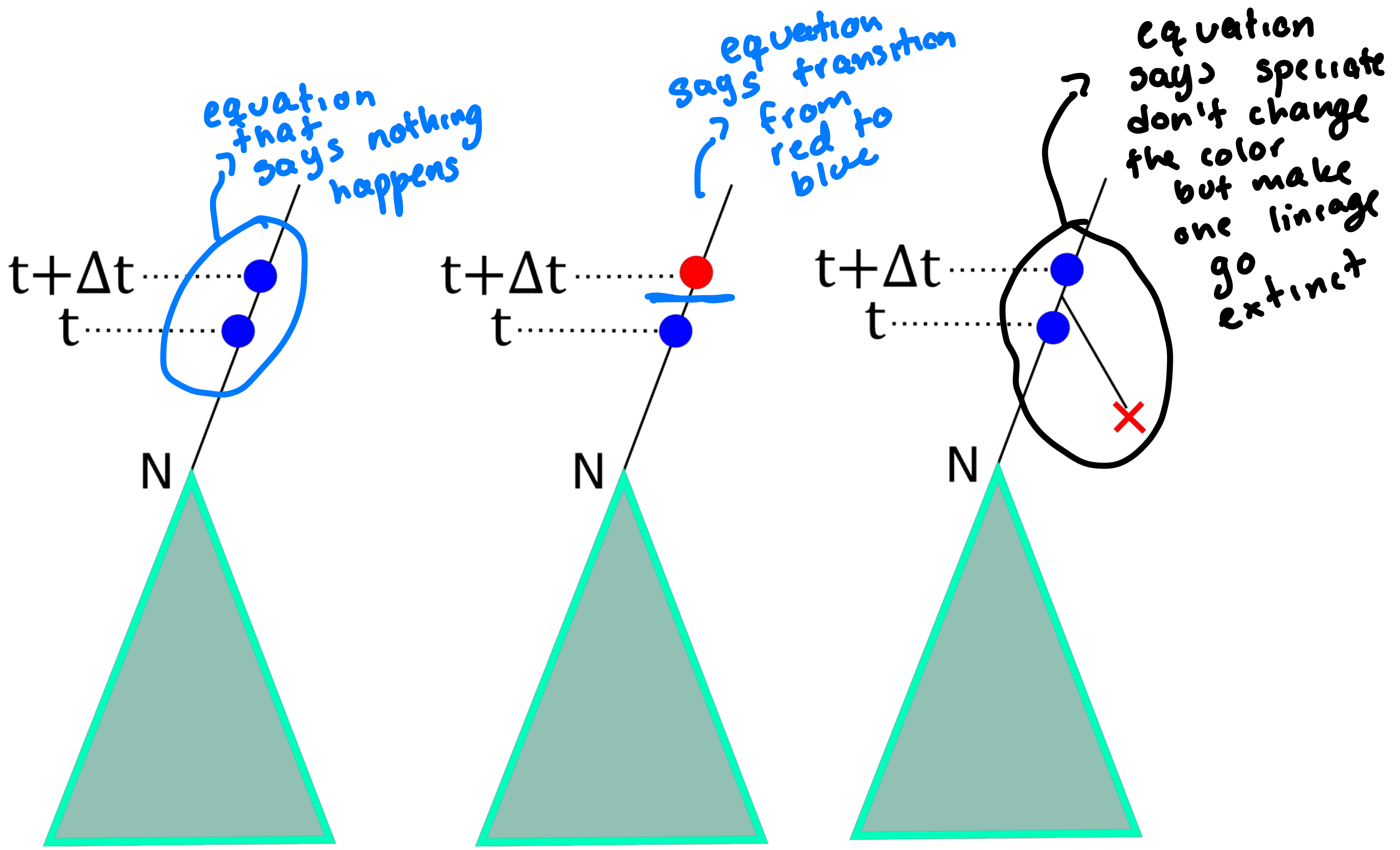
Phyloseminar
Dra. Sally Otto
BiSSE developer

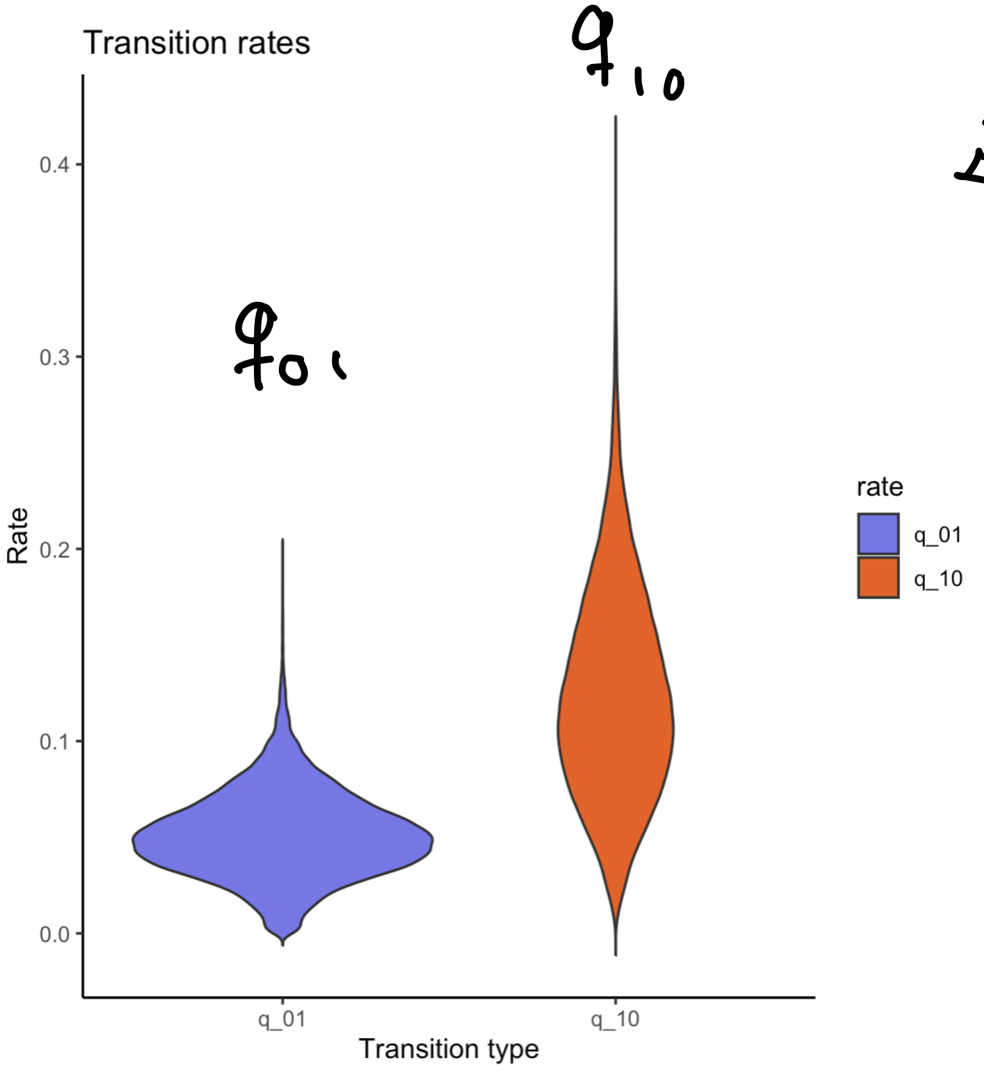
How do we specify a Q-matrix for this?

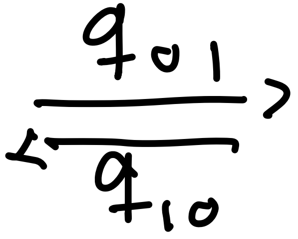
Binary state Speciation and Extinction Model (BiSSE)

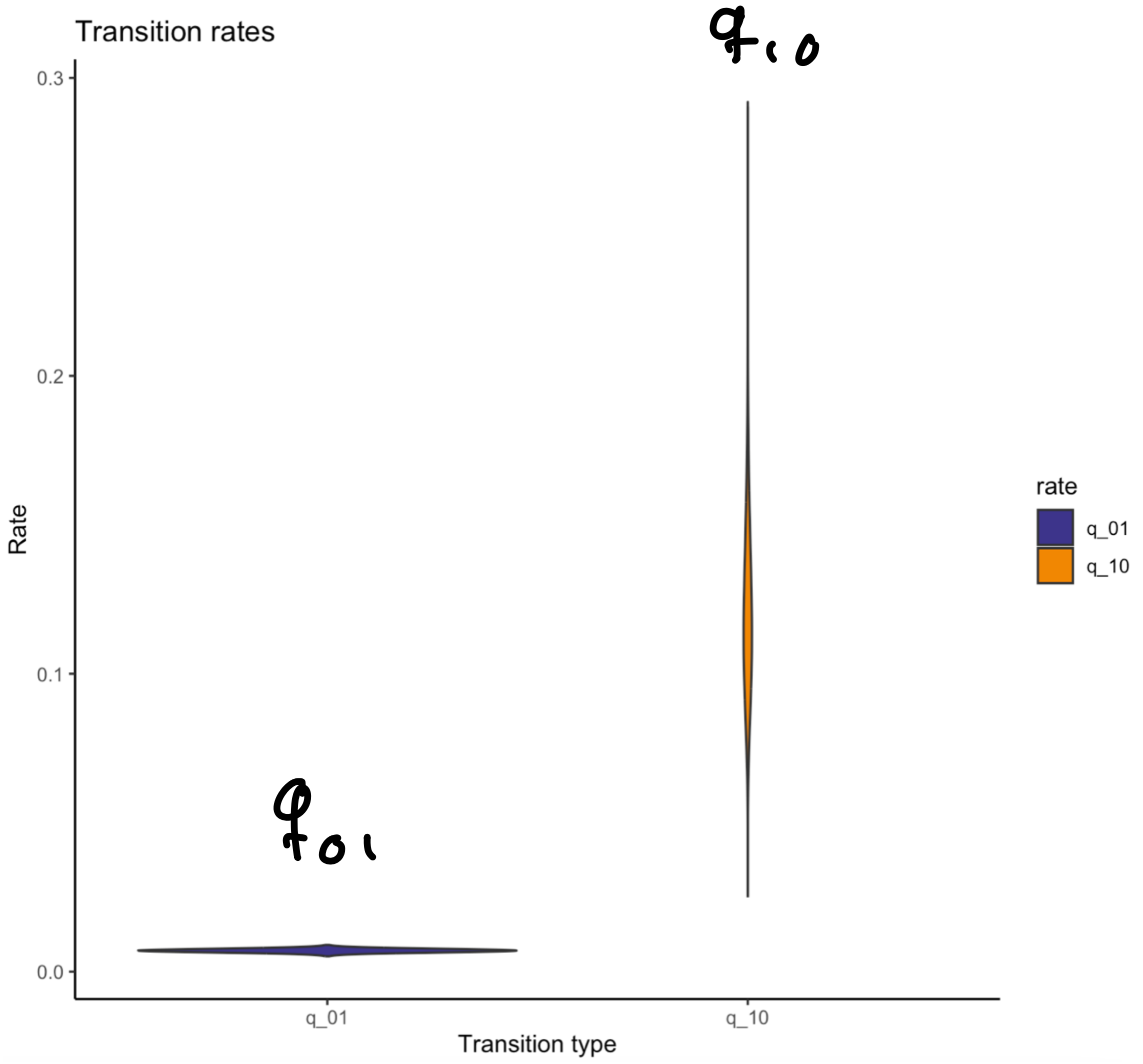
Maddison et al. 2007. *Systematic Biology*

Stochastic differential equations (Kolmogorov-Forward)









Mk2

Equal transitions back and forth from pollination

BiSSE

Easier to transition from Wind to Insect but uncertain

What about diversification?

- Net diversification $r_0 = \lambda_0 - \mu_0$
  (speciation - extinction in state 0)
- Turnover $\tau_0 = \lambda_0 + \mu_0$
- Extinction fraction $\dfrac{\mu_0}{\lambda_0 + \mu_0}$

How do we know BiSSE is THE ONE?

H_0: $\lambda_0 = \lambda_1$ and $\mu_0 = \mu_1$

Original null hypothesis

- speciation equal for 0 and 1
- extinction equal for 0 and 1

OR

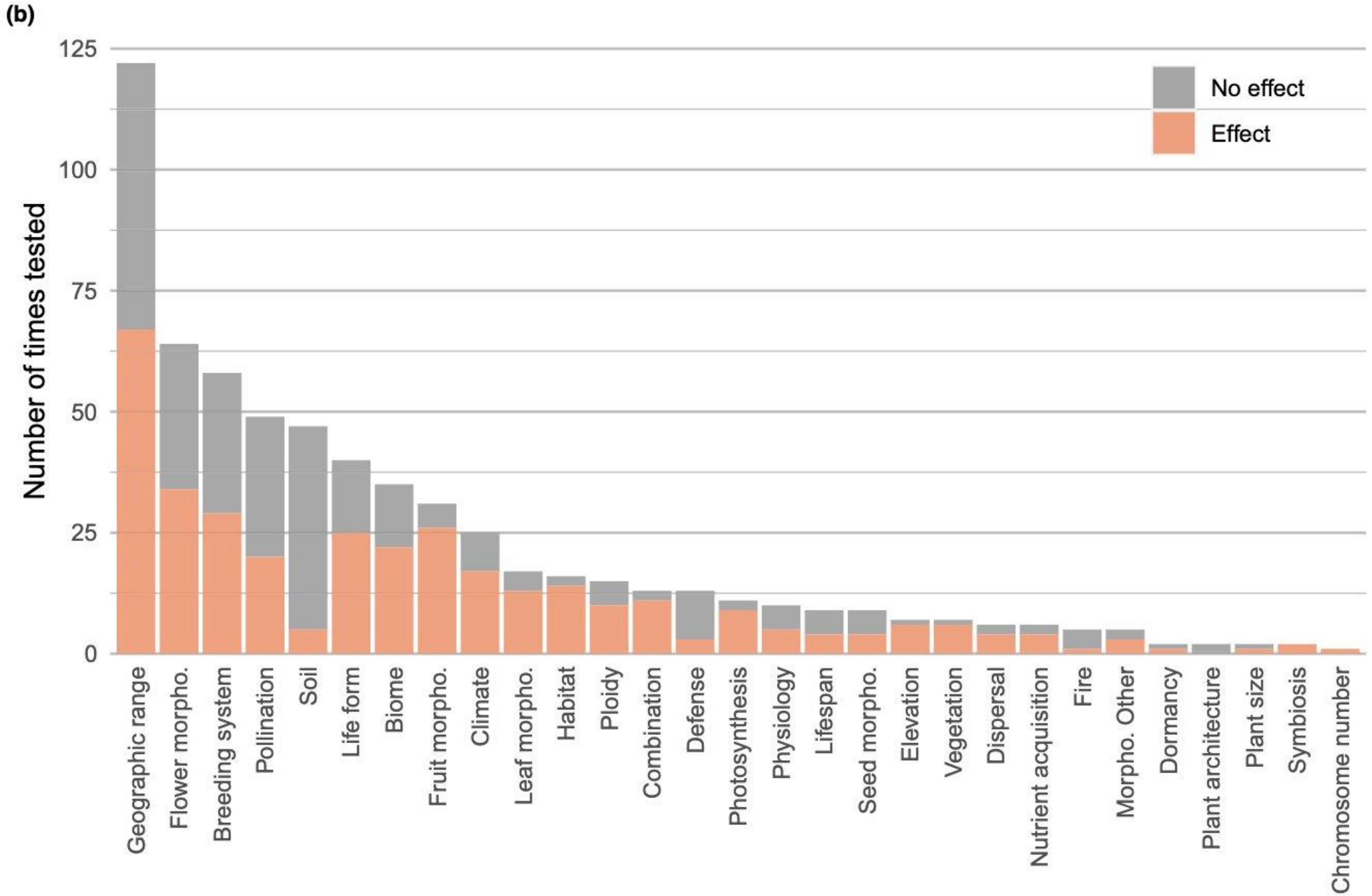
H_0: $r_0 = (\lambda_0 - \mu_0) = (\lambda_1 - \mu_1) = r_1$

$r_0 = r_1$

- net diversification equal for 0 and 1

BiSSE is the alternative hypothesis

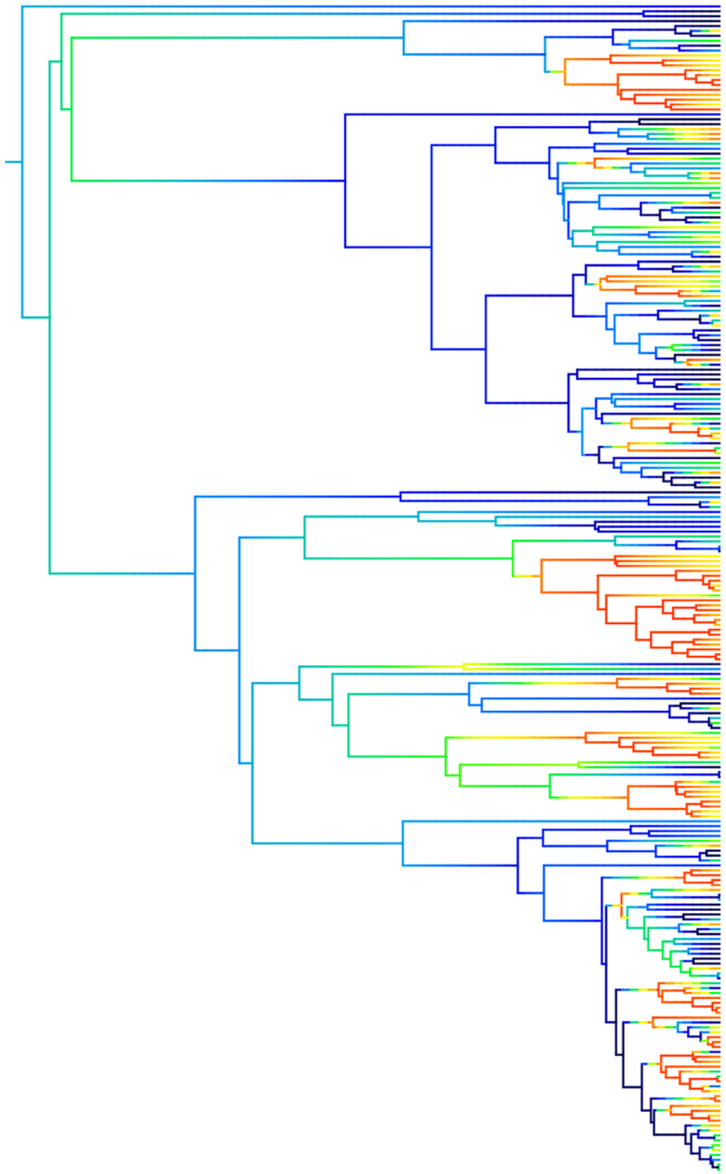
152 studies linking plant traits to speciation and extinction using state-dependent diversification



Helmstetter, A.J., Zenil-Ferguson, R., et al. 2022. *Ecology Letters*

Null hypothesis of BiSSE

$$H_0: r_0 = r_1$$



BiSSE's Null Hypothesis is too simple

$$H_0\colon r_0 = r_1$$

Type I error 50%

Misspecification of null hypothesis

New null H_0:
Something else can be modifying diversification other than my trait

Davis et al. 2013. *BMC Evolutionary Biology*
Rabosky and Goldberg 2015. *Sys Bio*

New null hypothesis- the hidden states

H_0: $\lambda_0 = \lambda_1$ and $\mu_0 = \mu_1$

H_0: $r_0 = (\lambda_0 - \mu_0) = (\lambda_1 - \mu_1) = r_1$