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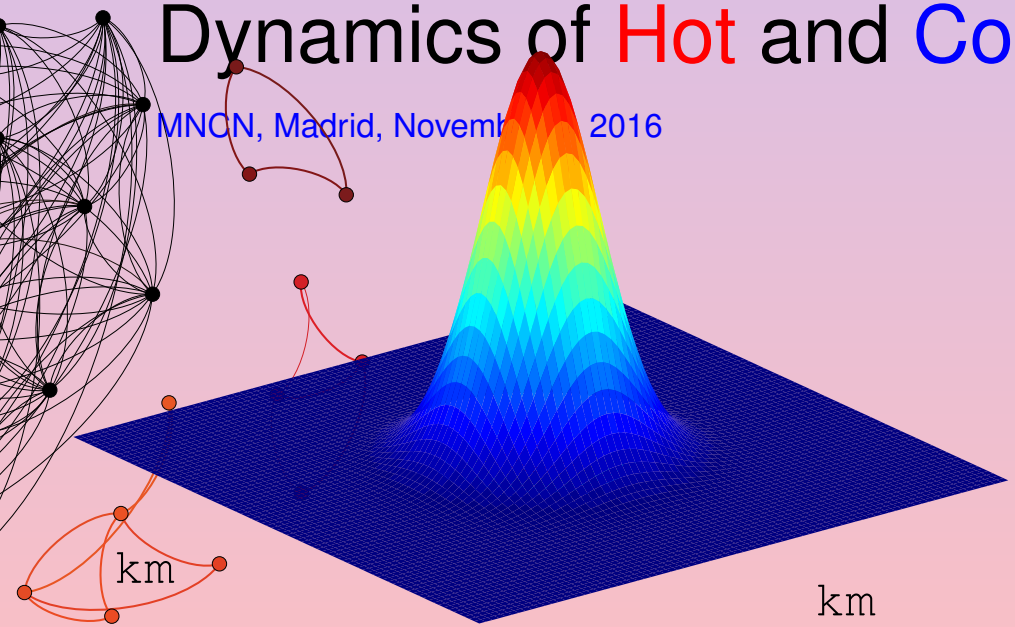
A Theory for Diversification and Biodiversity Dynamics of Hot and Cold Spots

MNCN, Madrid, Novemb[illegible] 2016



- What are hot spots?

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- What do we need to predict them?

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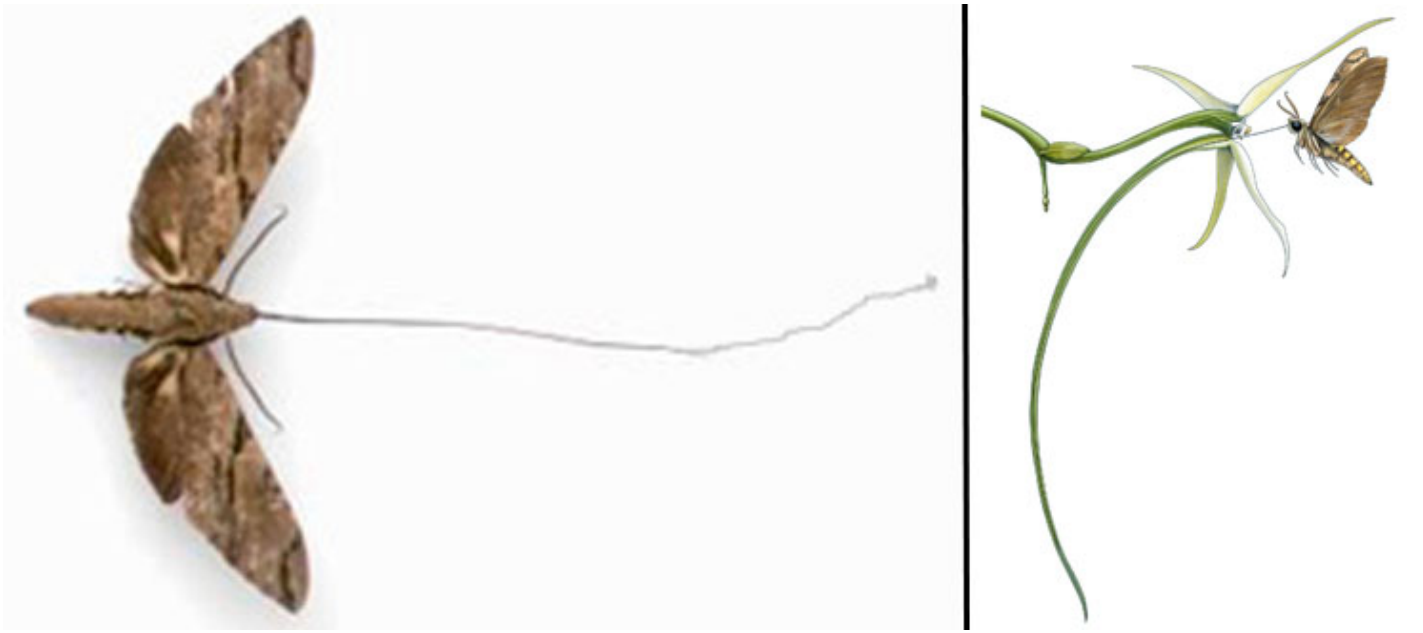
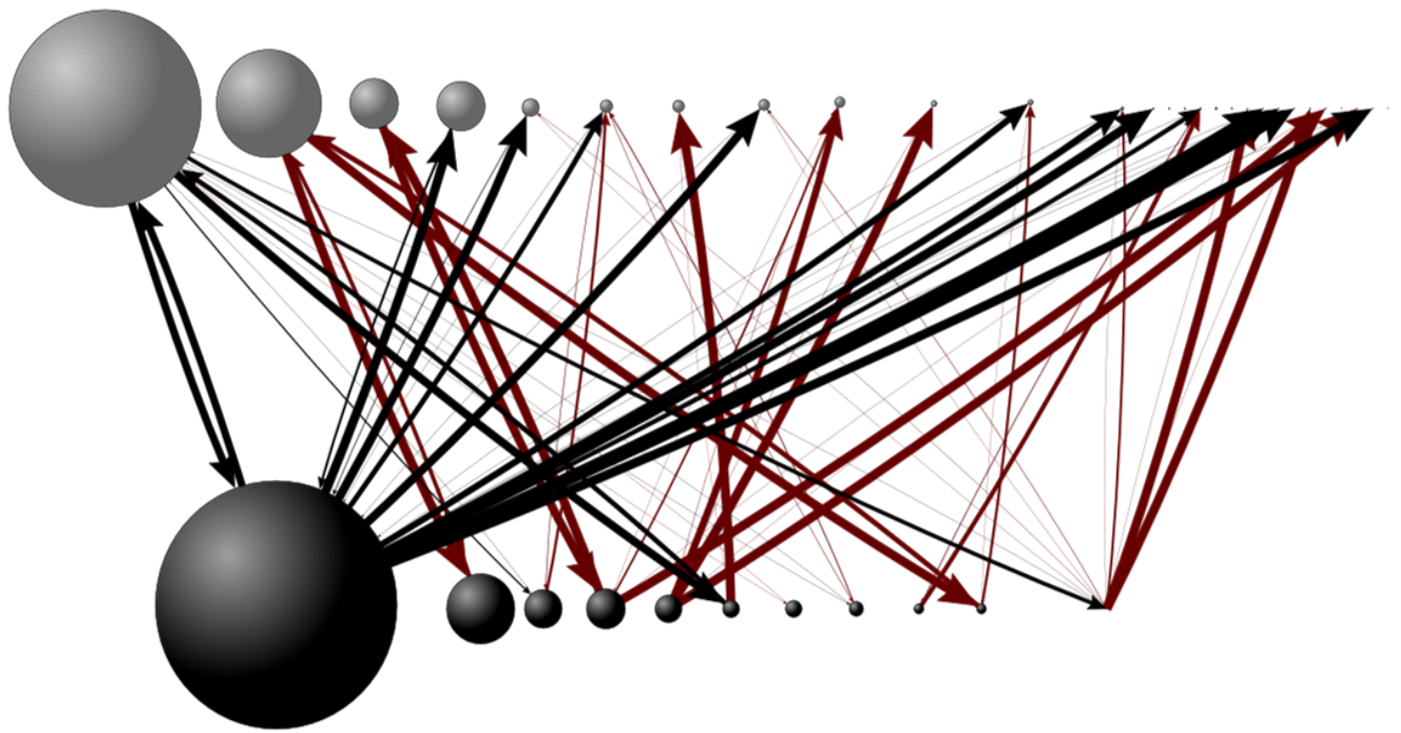
- Which are the existing theories?

Geographic mosaic theory of coevolution

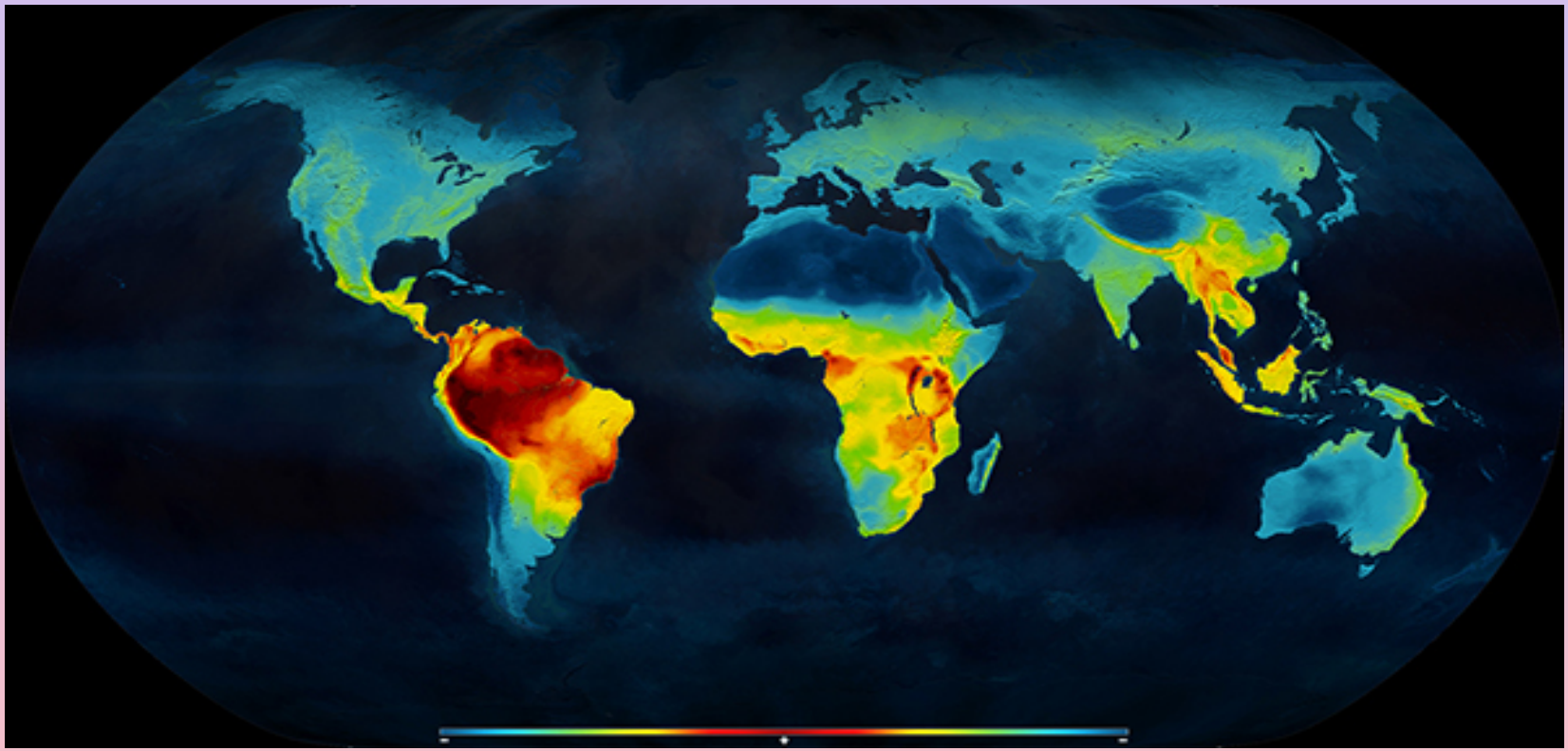


Thompson, J. N., et al. (1994). The coevolutionary process. *Univ. of Chicago Press, USA.*

Geographic mosaic theory of coevolution

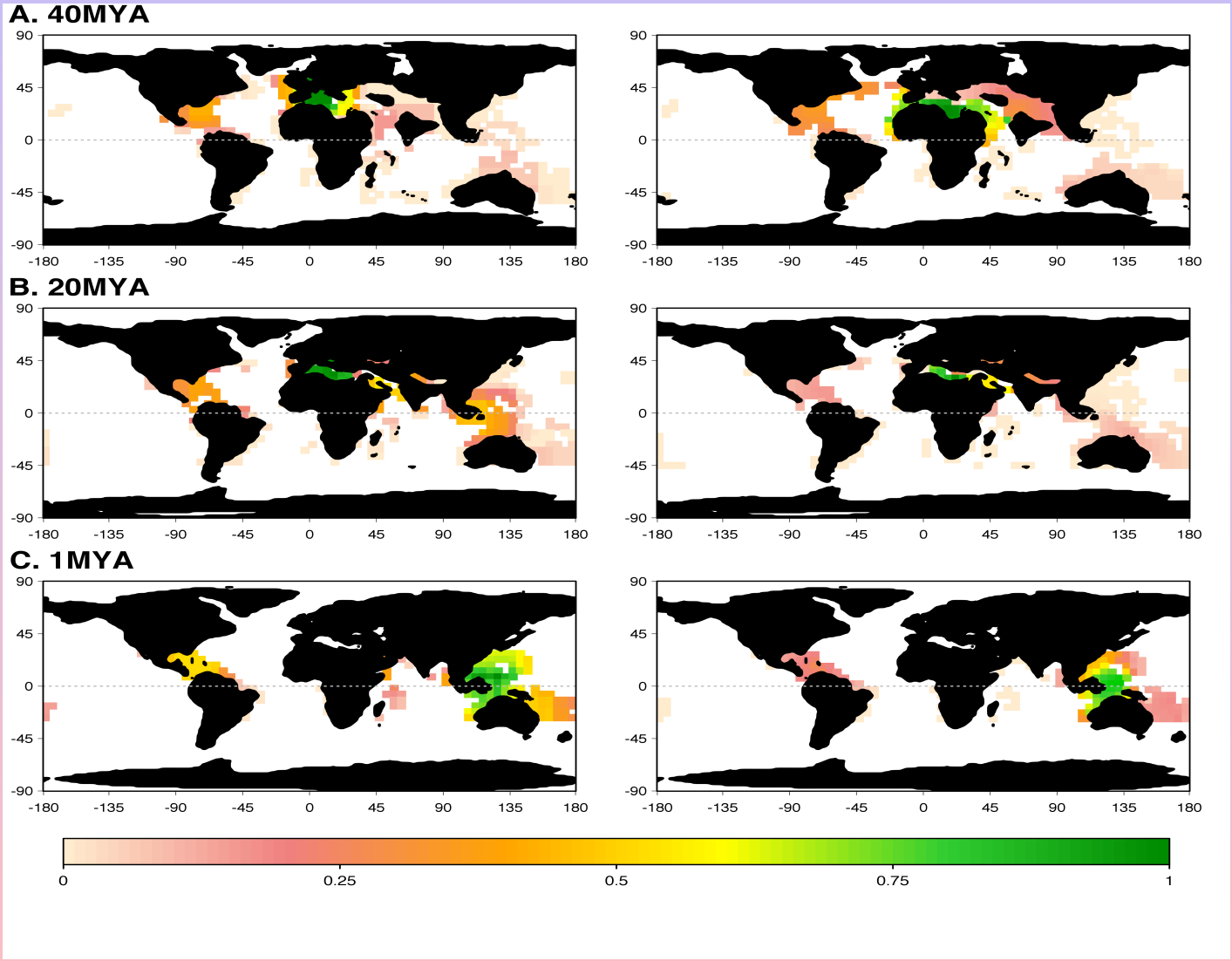


Fluctuating environments and gradients



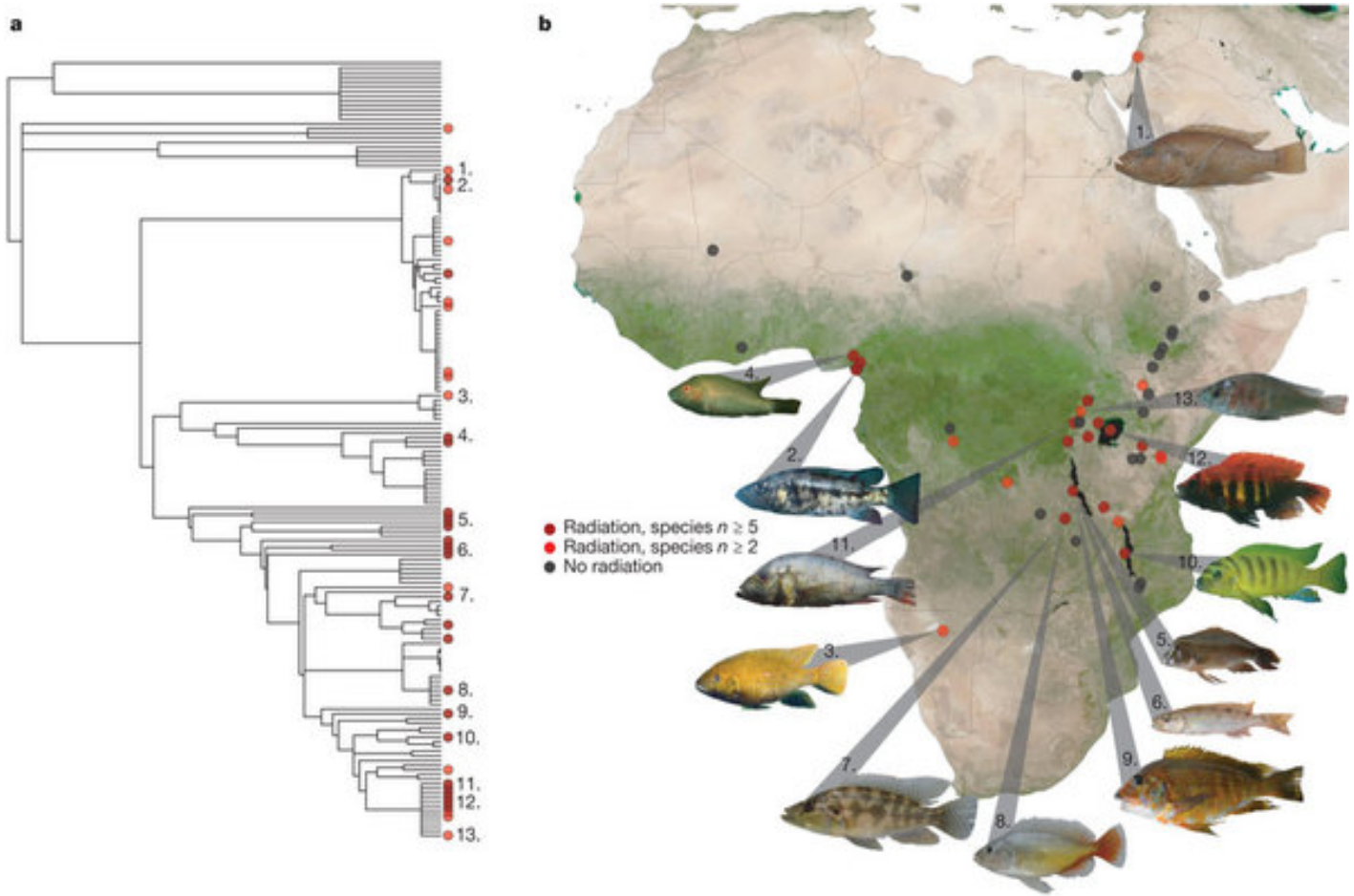
Mannion, P. D., et al. (2014). The latitudinal biodiversity gradient through deep time. *TREE*, 29:42-50.

Landscape dynamics and plate tectonics



Leprieur, F., et al. (2016). Plate tectonics drive tropical reef biodiversity dynamics. *Nat. comm.*, 7:11461.

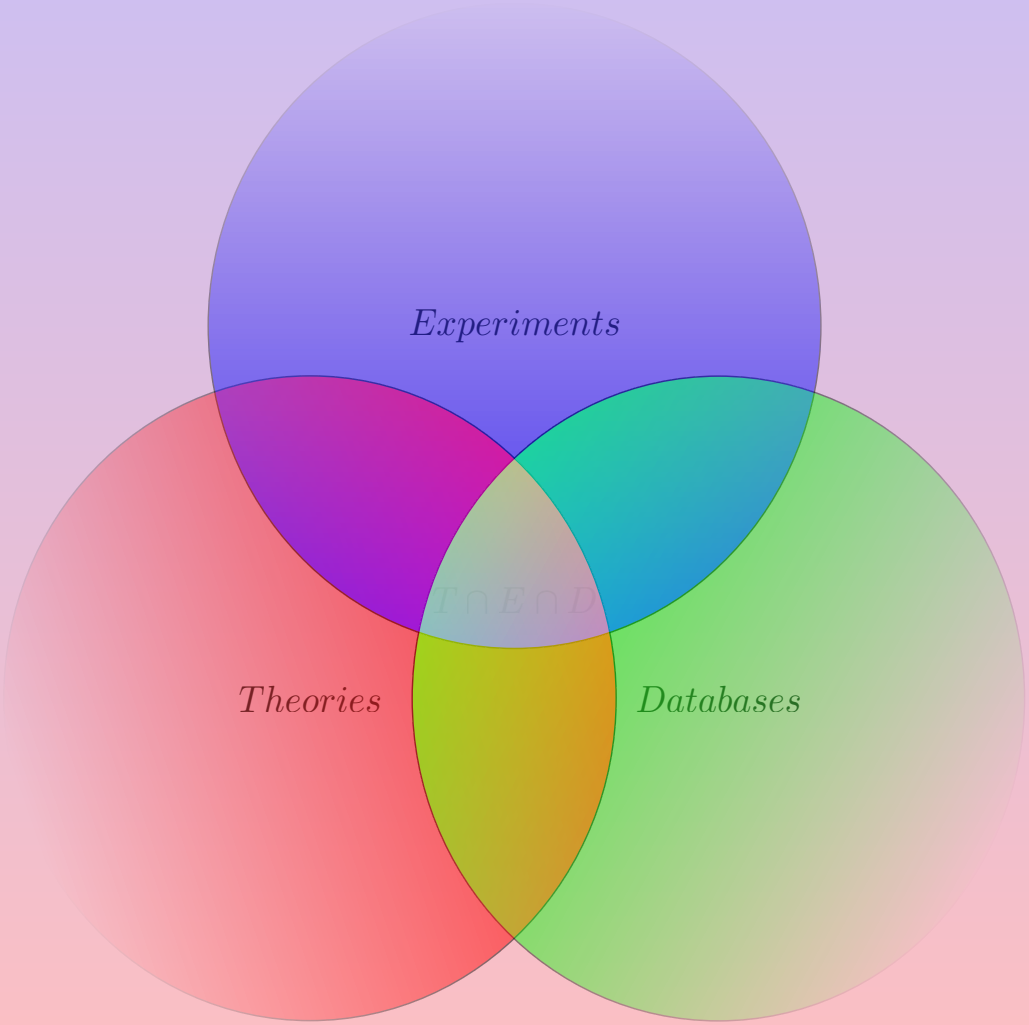
Sexual selection



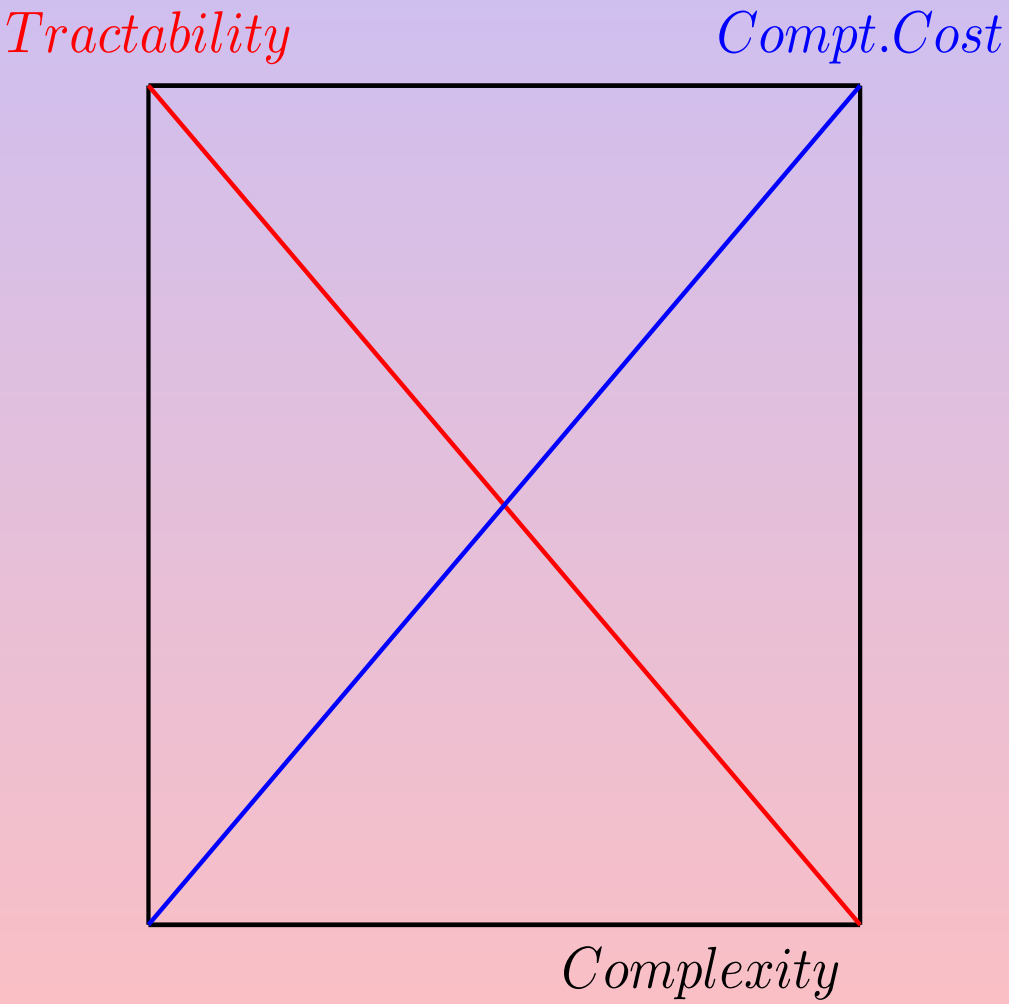
Wagner, C. E., et. al (2012). Ecological opportunity and sexual selection together predict adaptive radiation, *Nature*, 487:366-369.

Merging theories?

Tractability and reproducibility



Tractability and reproducibility



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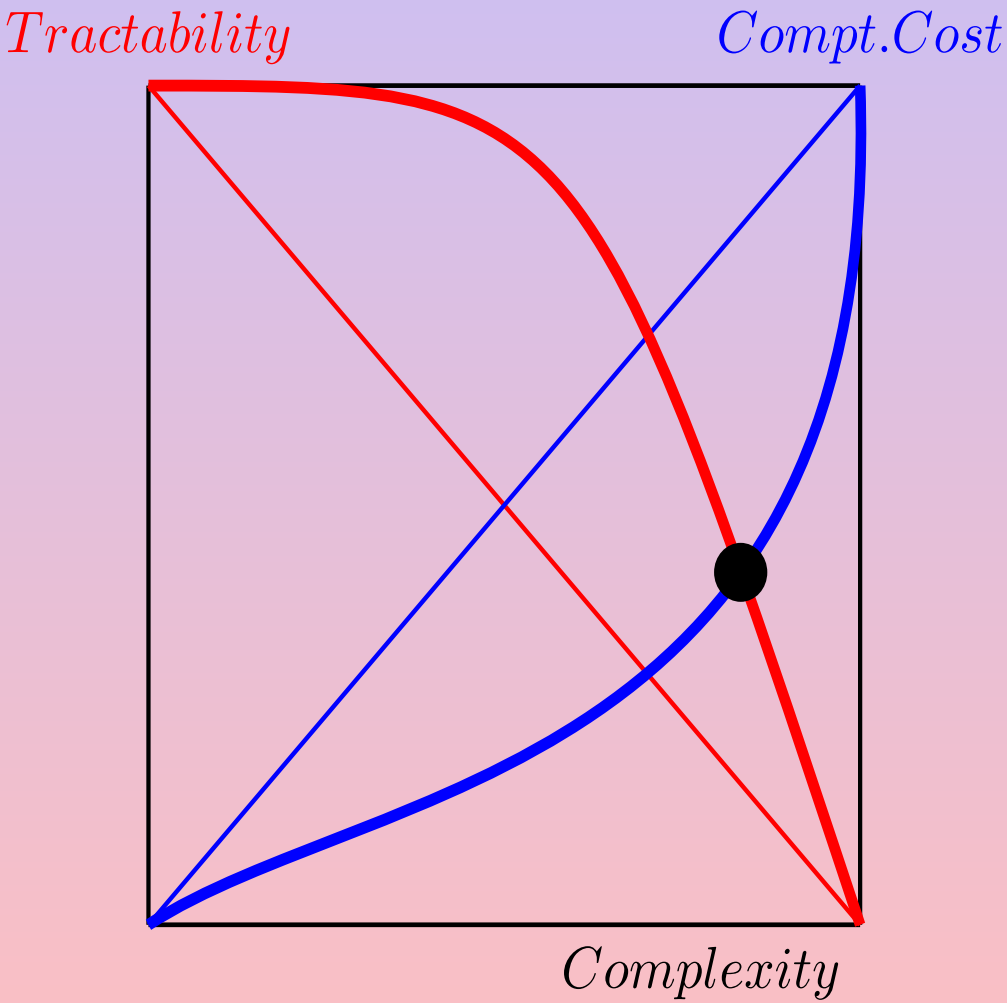
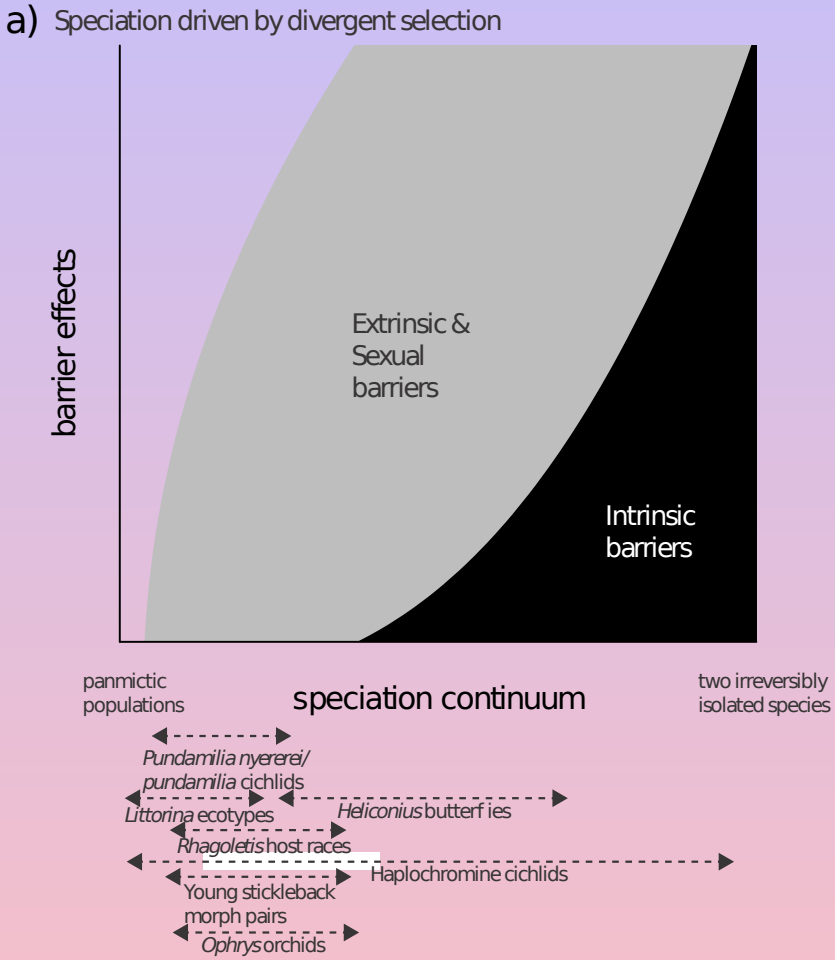
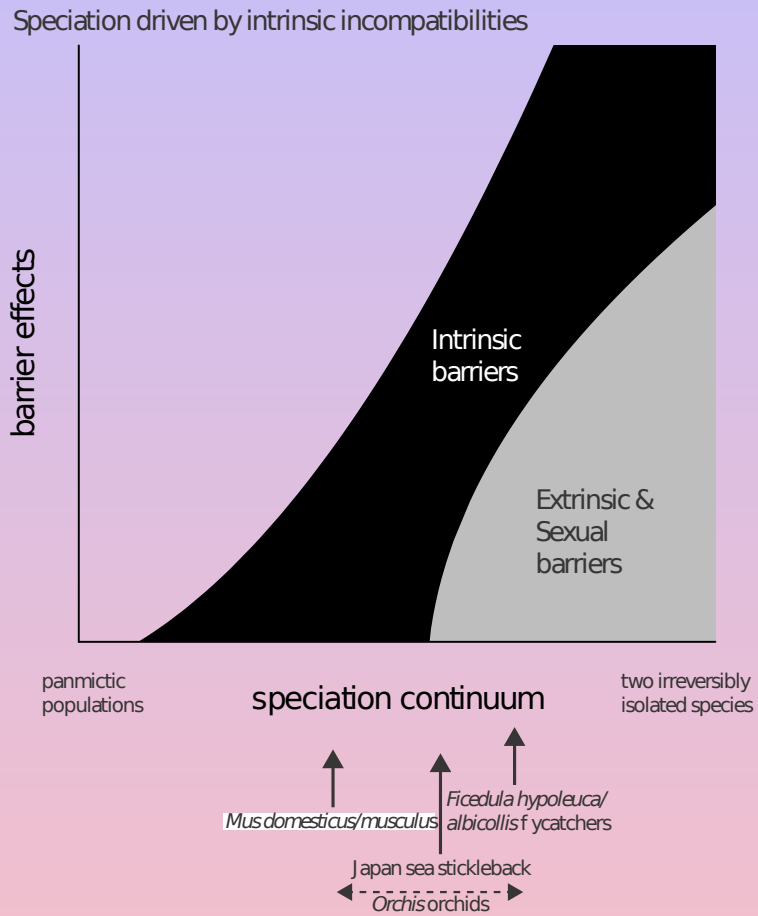


Questions

- Does neutral diversification predict the biogeography of hot and cold spots?

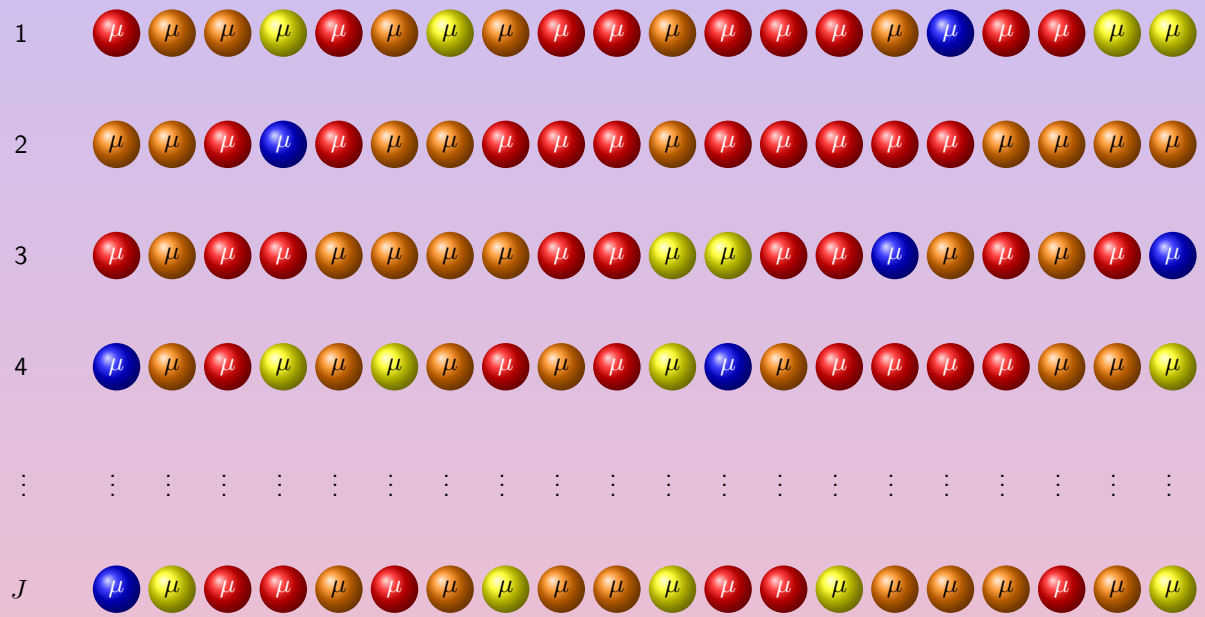
Ecological and non-ecological speciation



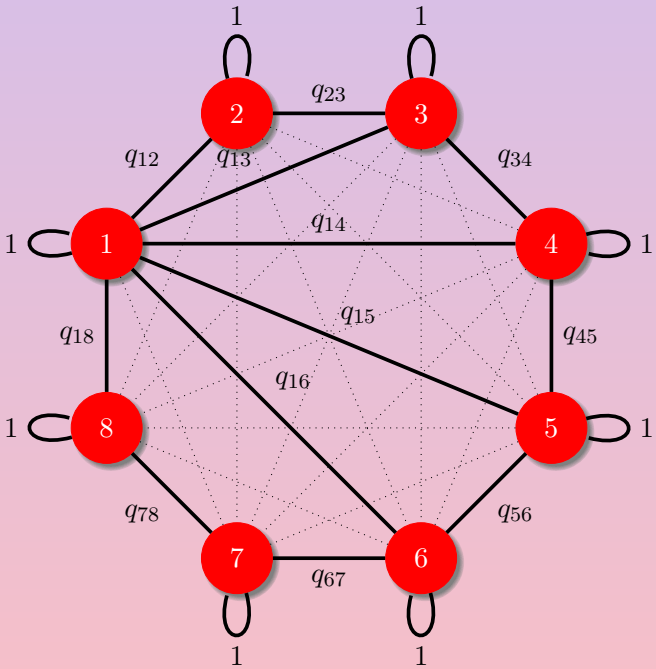


Seehausen, O., et al. (2014). Genomics and the origin of species. *Nature Reviews Genetics*, 15:176-192

Population size, $\mathcal{J}$, Genome size, $\mathcal{L}$, and mutation rate, μ

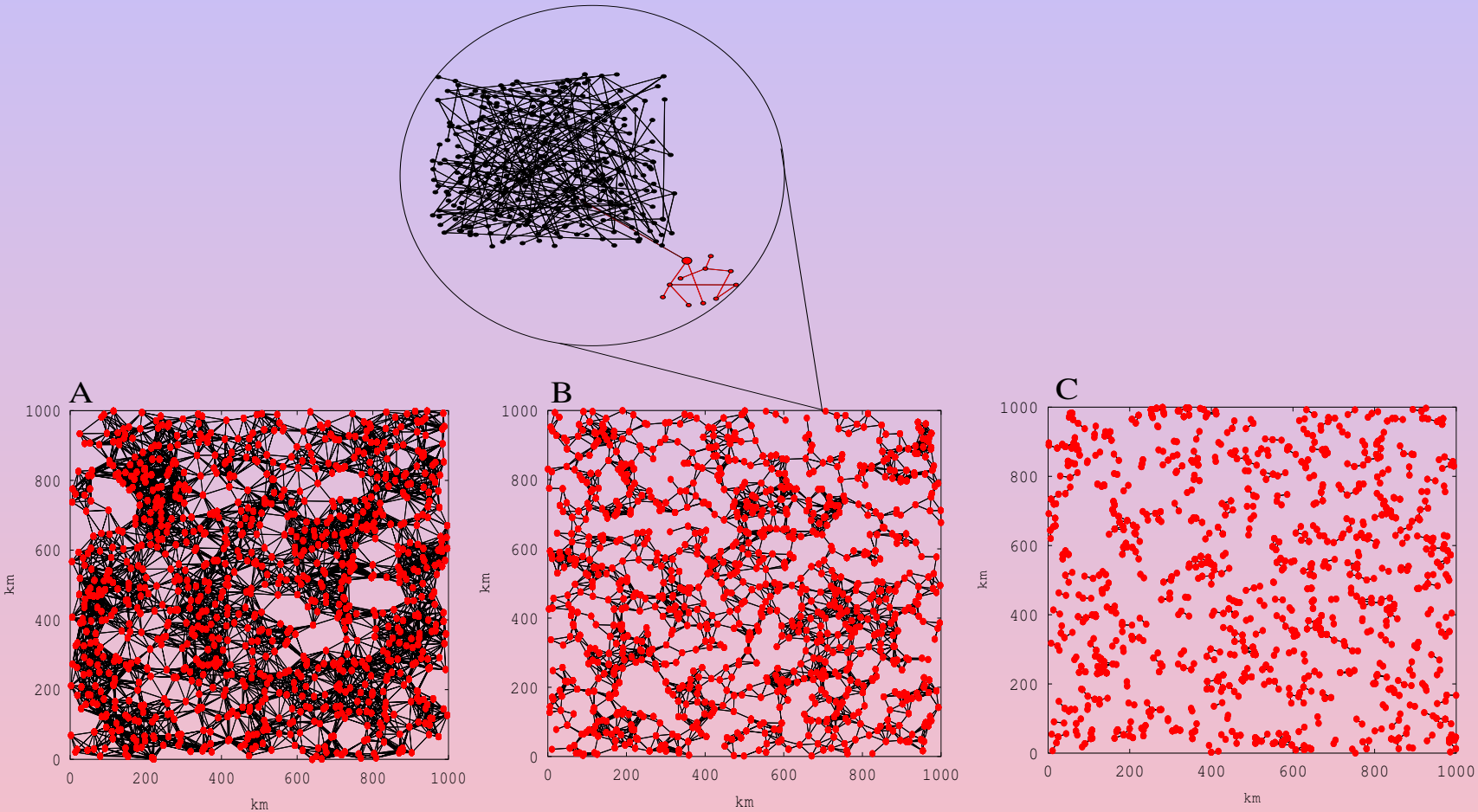


Genomes in a mating graph (threshold, $\mathcal{Q}_{min}$); $Q = [q_{ij}]$ and $q_{ij} > \mathcal{Q}_{min}$



$$\mathbf{Q} = \begin{bmatrix} & \mathbf{1} & \mathbf{2} & \mathbf{3} & \mathbf{4} & \mathbf{5} & \mathbf{6} & \mathbf{7} & \mathbf{8} \\ \mathbf{1} & 1 & q_{12} & q_{13} & q_{14} & q_{15} & q_{16} & 0 & q_{18} \\ \mathbf{2} & q_{21} & 1 & q_{23} & 0 & 0 & 0 & 0 & 0 \\ \mathbf{3} & q_{31} & q_{32} & 1 & q_{34} & 0 & 0 & 0 & 0 \\ \mathbf{4} & q_{41} & 0 & q_{43} & 1 & q_{45} & 0 & 0 & 0 \\ \mathbf{5} & q_{51} & 0 & 0 & q_{54} & 1 & q_{56} & 0 & 0 \\ \mathbf{6} & q_{61} & 0 & 0 & 0 & q_{65} & 1 & q_{67} & 0 \\ \mathbf{7} & 0 & 0 & 0 & 0 & 0 & q_{76} & 1 & q_{78} \\ \mathbf{8} & q_{81} & 0 & 0 & 0 & 0 & 0 & q_{87} & 1 \end{bmatrix}$$

Genomes in the landscape (threshold, $\mathcal{D}_{max}$); $D = [d_{ij}]$ and $d_{ij} \leq D_{max}$



Gene flow, ($\mathcal{M}$)

Symmetric gene flow

$$m_{ij}^{k} = \frac{\mathcal{M}}{d_{ij}} \tag{1}$$

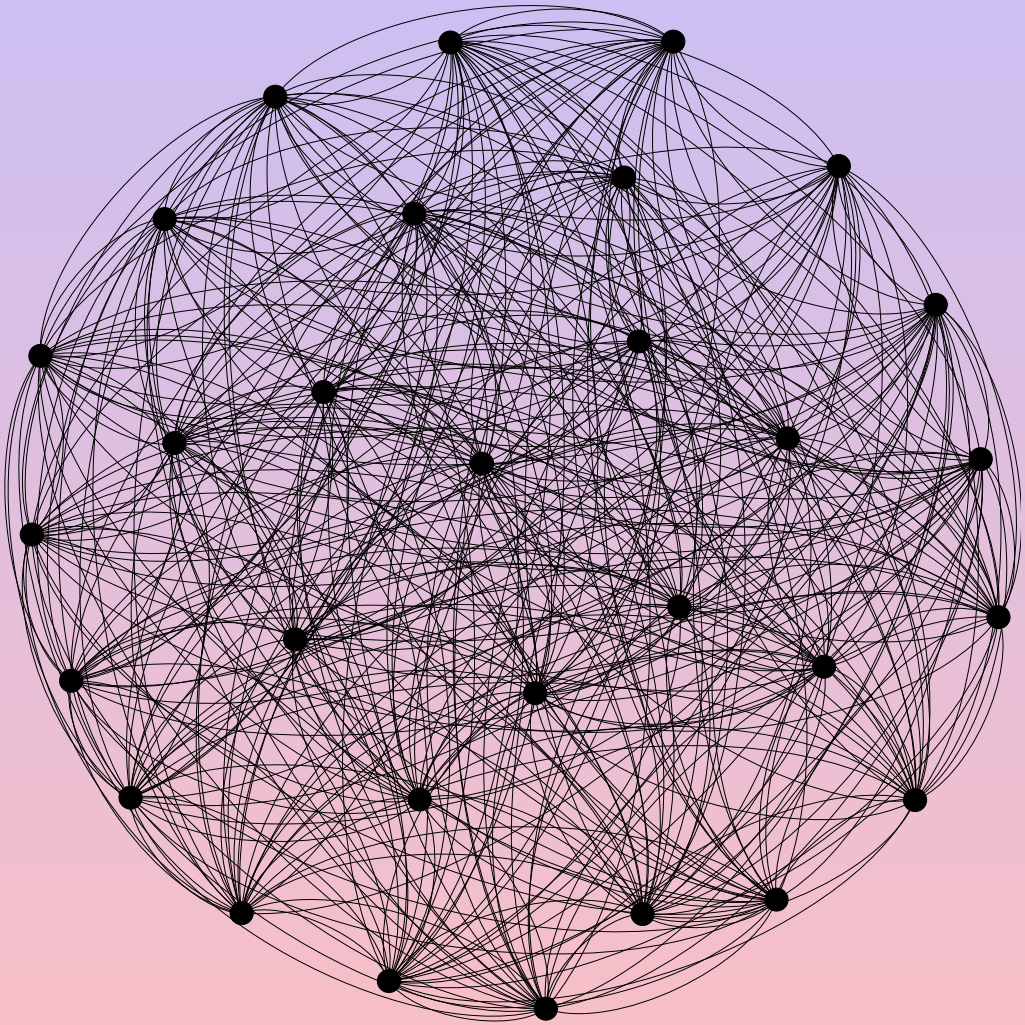
Centripetal gene flow

$$m_{ij}^{k} = \begin{cases} \frac{\mathcal{M}}{d_{ij}} & \text{if } \sum_{l=1}^{\mathcal{S}} d_{il} \leq \sum_{l=1}^{\mathcal{S}} d_{jl}, \\ 0 & \text{if } \sum_{l=1}^{\mathcal{S}} d_{il} > \sum_{l=1}^{\mathcal{S}} d_{jl} \end{cases} \tag{2}$$

Centrifugal gene flow

$$m_{ij}^{k} = \begin{cases} \frac{\mathcal{M}}{d_{ij}} & \text{if } \sum_{l=1}^{\mathcal{S}} d_{il} \geq \sum_{l=1}^{\mathcal{S}} d_{jl}, \\ 0 & \text{if } \sum_{l=1}^{\mathcal{S}} d_{il} < \sum_{l=1}^{\mathcal{S}} d_{jl} \end{cases} \tag{3}$$

Given $\mathcal{I}$, μ, $\mathcal{Q}_{min}$ and $\mathcal{D}_{max}$ = 1, do we find isolated clusters in the graph?



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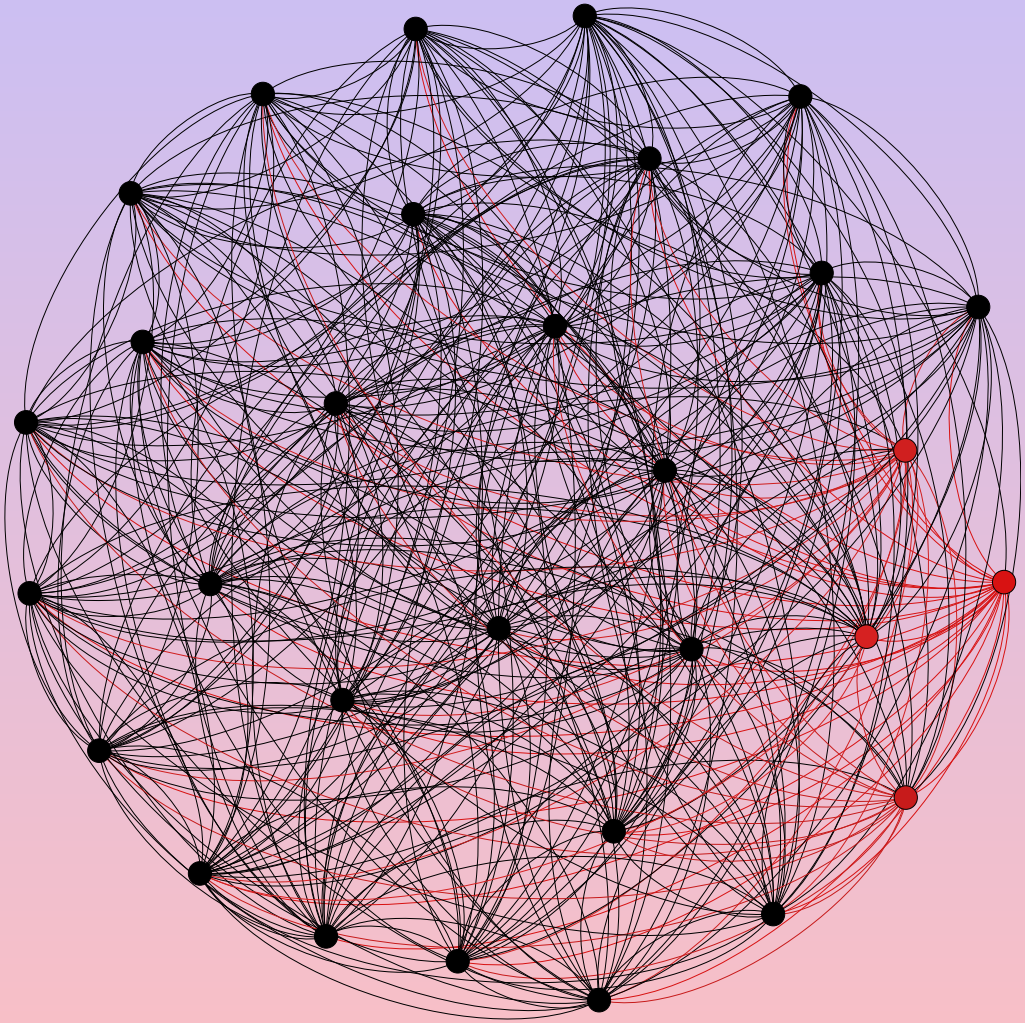

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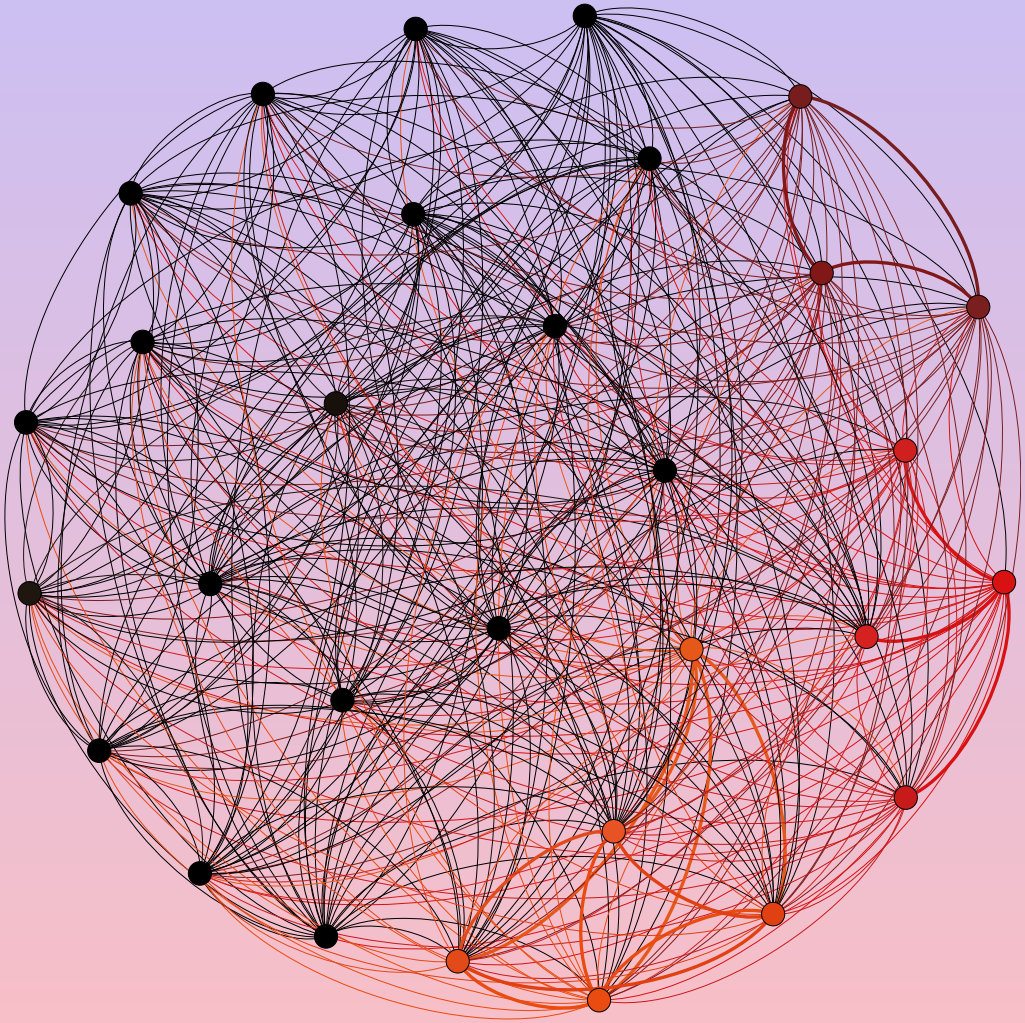

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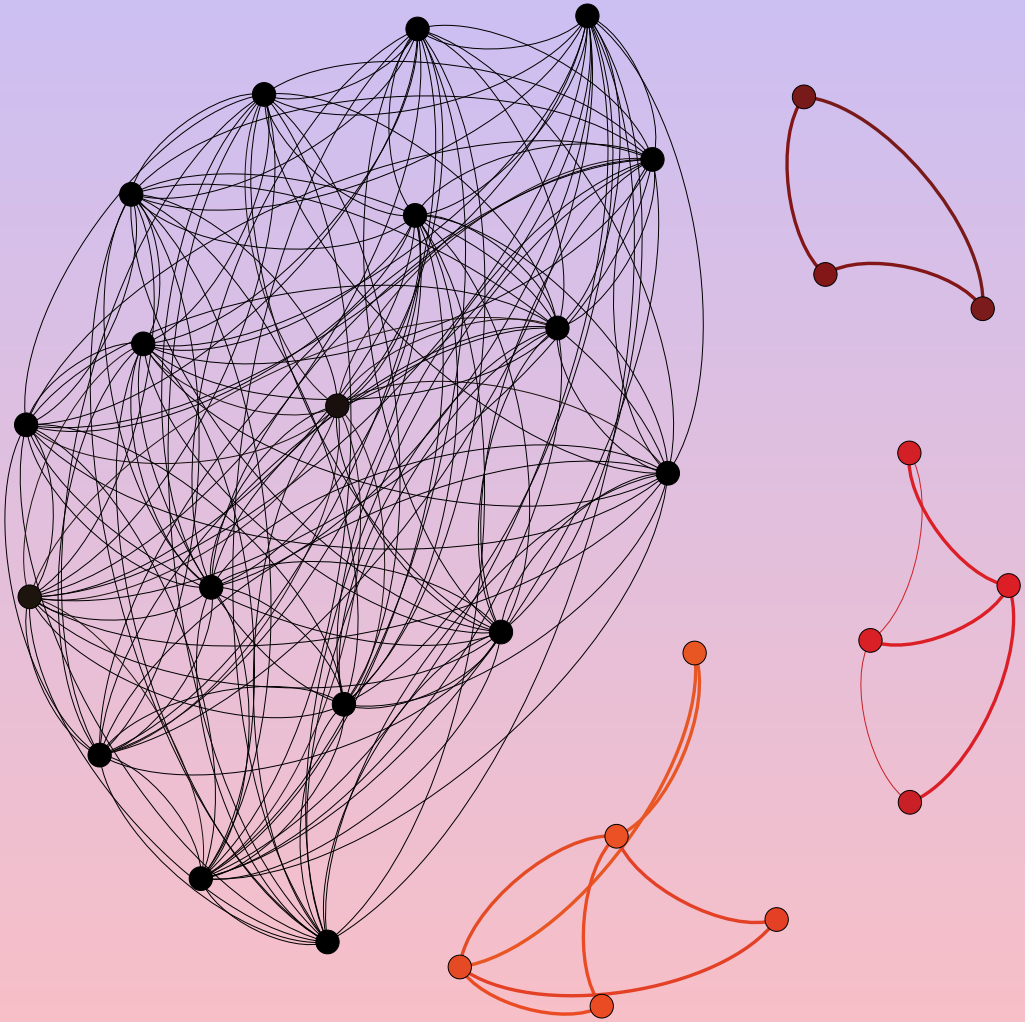


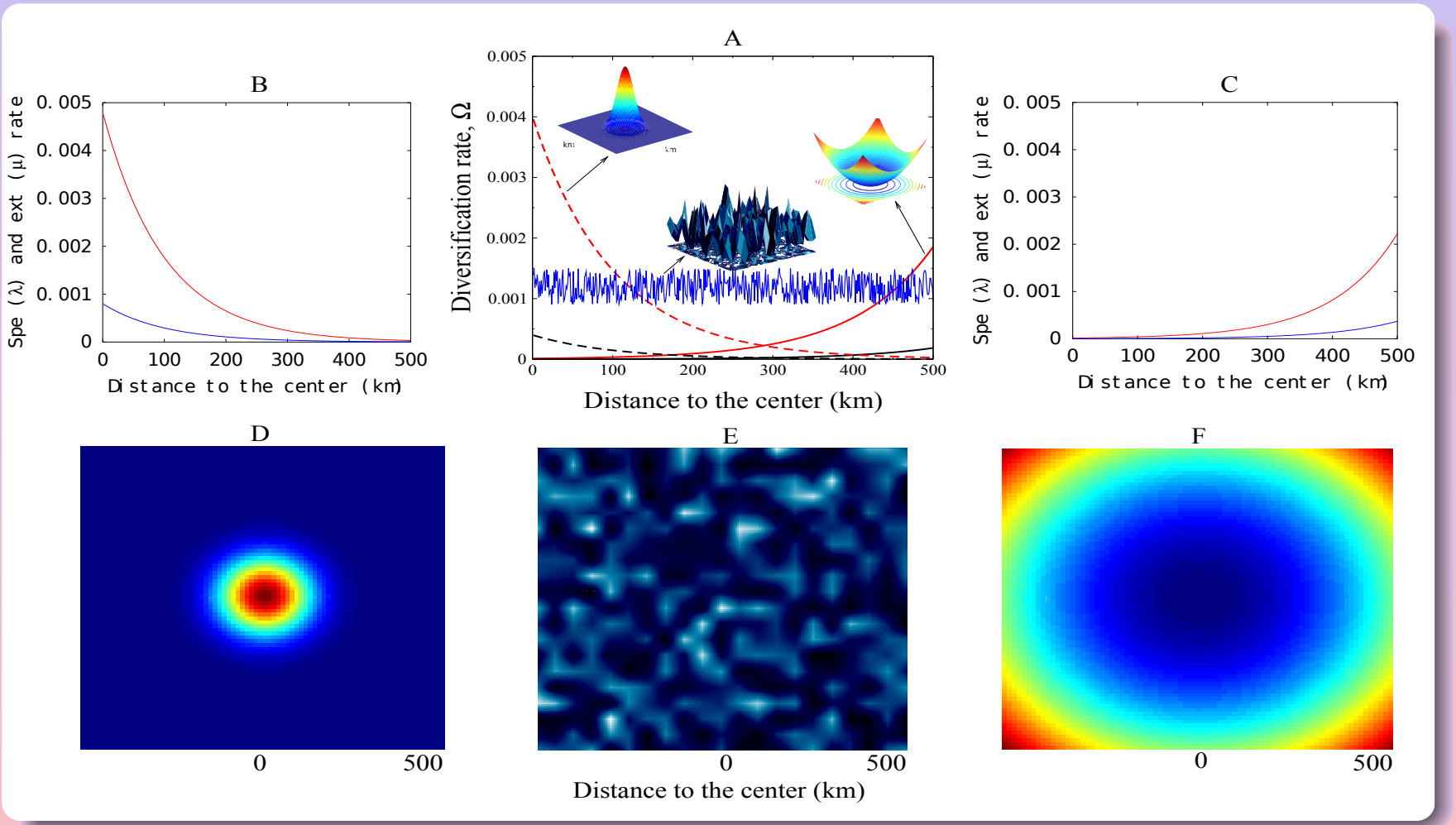
- Given $\mathcal{J}$, μ, $\mathcal{D}_{max}$ = 1, and $\mathcal{Q}_{min} > Q^* \rightarrow Q^* = \frac{1}{4J\mu+1}$

  Sexual reproduction: $\rightarrow n^*_{sex} = \frac{log(\mathcal{Q}_{min})}{-2\mu+log[(\mathcal{Q}_{min}+3)/4]}$

Melián, C. J., et al. (2010). Frequency-dependent selection predicts patterns of radiations and biodiversity. *PLoS Comput Biol*, 6(8):1000892.

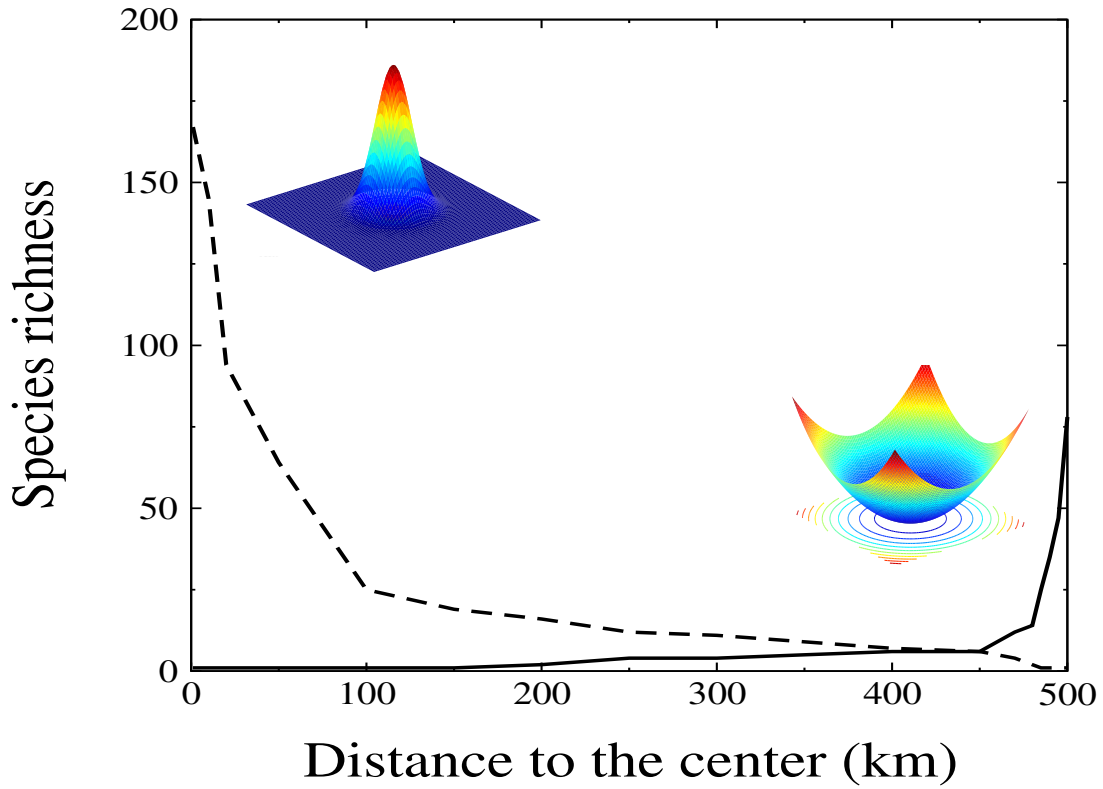
Melián, C. J., et al. (2012). Does sex speed up evolutionary rate and increase biodiversity. *PLoS Comput Biol*, 8(3):1002414.

Hot and cold spots ($\mathcal{I}$,$\mathcal{L}$,μ,$\mathcal{Q}_{min}$,$\mathcal{D}_{max}$,$\mathcal{M}$)



Melián, C. J., et al. Diversification and biodiversity dynamics of hot and cold spots (2015). *Ecography*, 38:393–401.

Hot spots and species richness



Outlook

- Narrowing down the micro-macroevolution gap

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- Centripetal gene flow model predicts hot spots in the center of the distribution ranges of diversifying lineages

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- In static landscapes, landscape structure, the strength of assortative mating and the intensity and directionality of gene flow may play a critical role to anticipate the formation of hot and cold spots
- Centripetal gene flow model predicts hot spots in the center of the distribution ranges of diversifying lineages
- CHALLENGE: Realistic (and testable) diversification models to infer the mechanisms predicting large scale biodiversity patterns

Thank you!

- Computing-scientist staff at NCEAS, University of California Santa Barbara.
- Swiss National Science Foundation