

# 7. The Assembly of Diversity

## Regional Processes

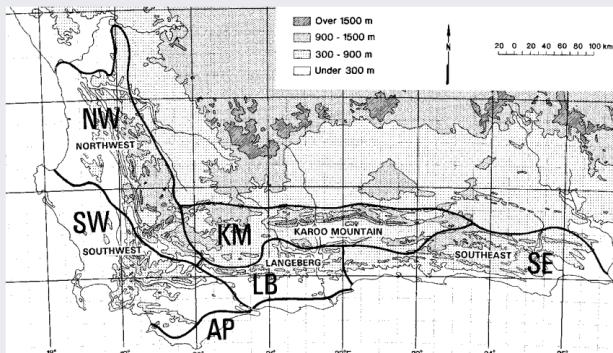
Jasper Slingsby, BIO3018F

2024-01-31

# Local vs Regional scale processes

The diversity of local biological communities is a balance of regional and local processes - Ricklefs 1987

## Regional scale



## Local scale

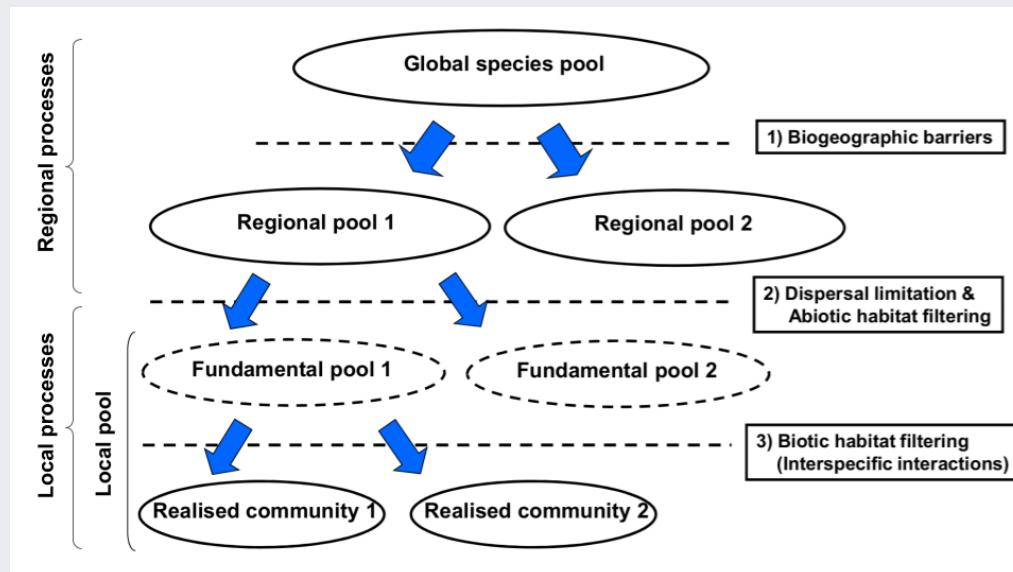


- speciation
- extinction
- dispersal (immigration, emigration)

- environmental filtering
- interspecific interactions (competition, predation, pathogens, mutualisms)
- adaptation
- stochastic variation

# Assembly of species pools across scales

Community assembly can be thought of as the successive filtering of species pools descending in spatial (and temporal) scale from global to local



We often split it into **regional** versus **local** processes

*Global species pool* = all species on the planet (or in the defined study domain, e.g. Cape Floral Region)

*Regional species pools* = the species that are present in each region (e.g. a biogeographic region or mountain), limited by barriers to dispersal

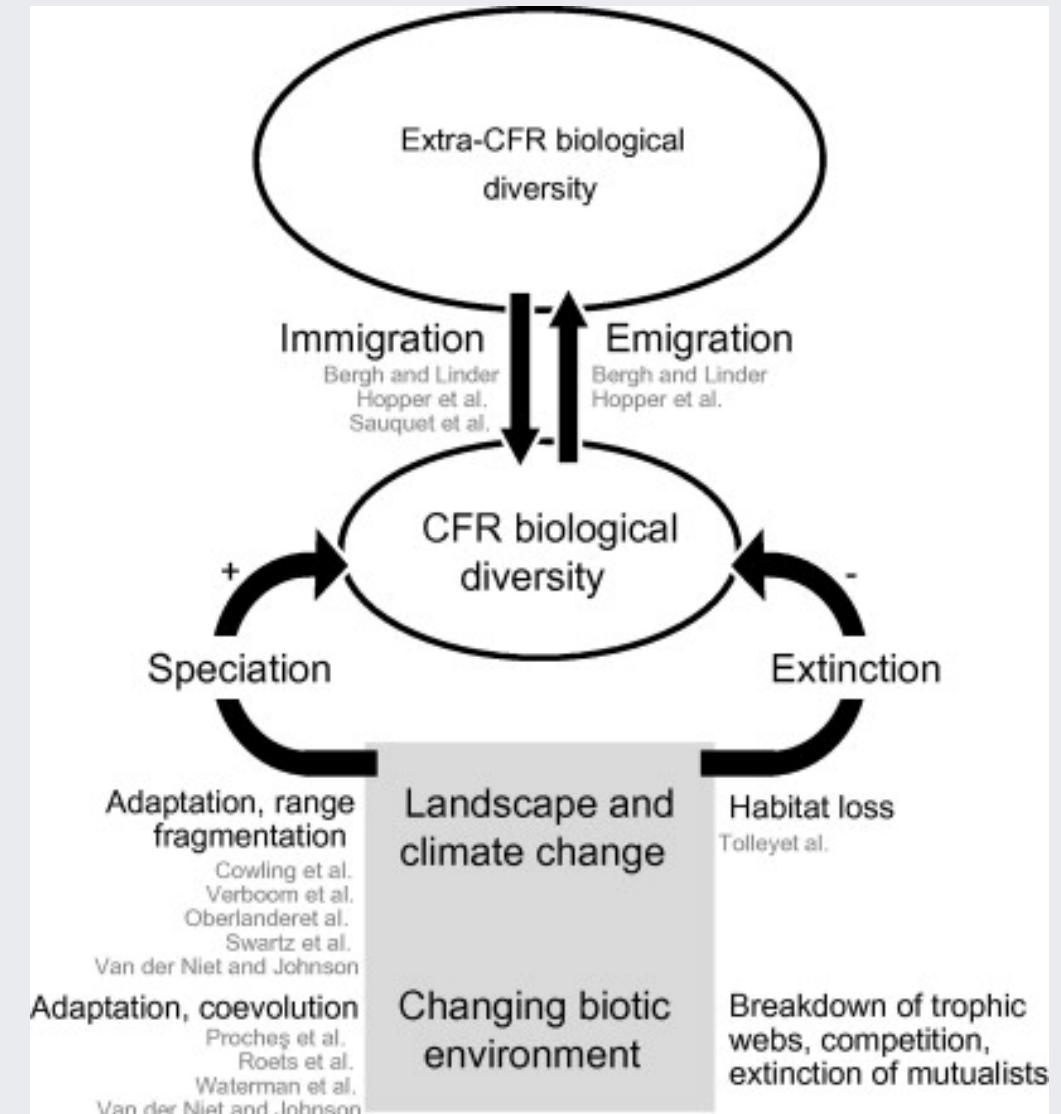
*Fundamental species pool* = species with the potential to occur in a particular location (i.e. can disperse there and find the appropriate abiotic conditions)

*Realised community* = the actual observed local community (i.e. a subset of the fundamental species pool with the ability to coexist, either stably or unstably)

*Functional or phylogenetic structure can be created or altered at any step...*

# Regional processes

- speciation
- extinction
- dispersal (immigration, emigration)



Verboom et al. 2009 (CFR = Cape Floristic Region)

# Speciation

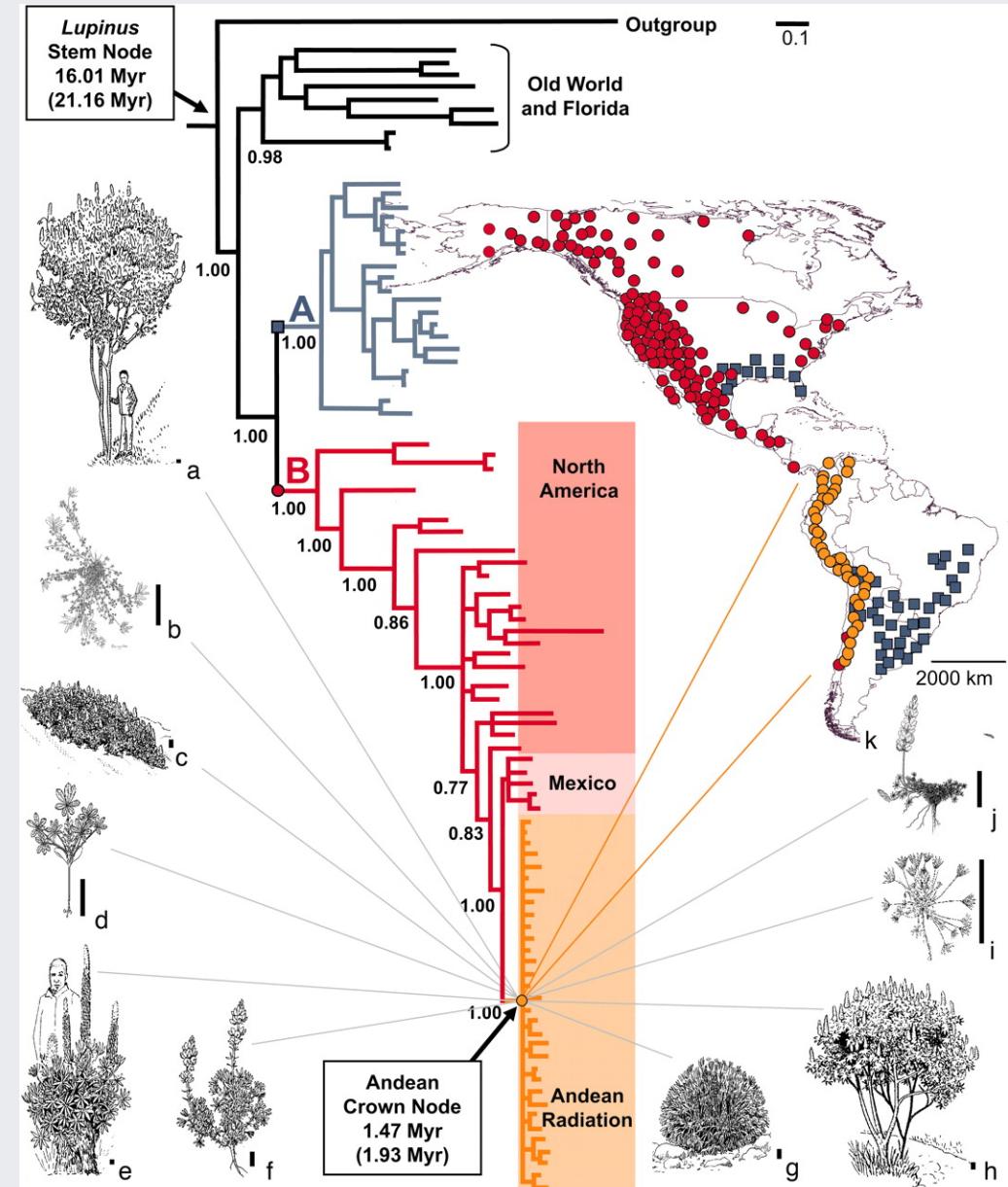
Driven by many processes, but dramatic radiations often triggered by major events/changes that create **new habitats and opportunities** for adaptive divergence, or cause **isolation**, or both.

E.g. The "Andean radiation" of the genus *Lupinus* was driven by the uplift of the Andes

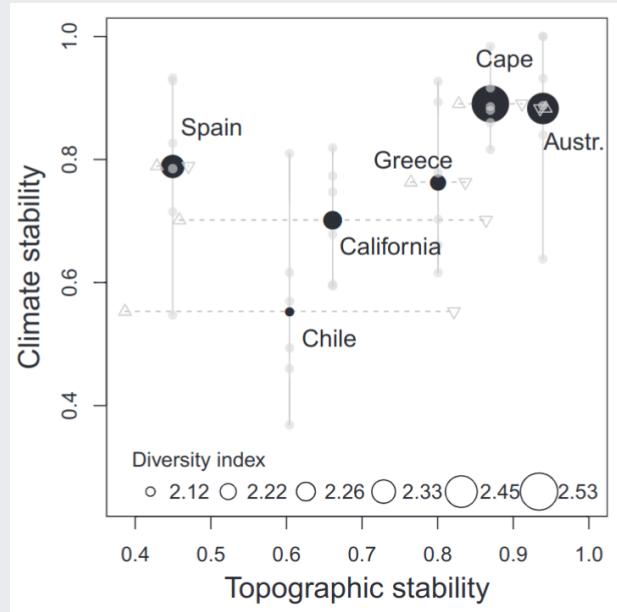
The uplift created diverse new habitats, because it created steep climatic gradients and exposed new geology/soils.

It also split populations by creating new barriers to dispersal (e.g. high mountains between lowland populations, or deep valleys between high elevation populations).

Hughes and Eastwood 2006

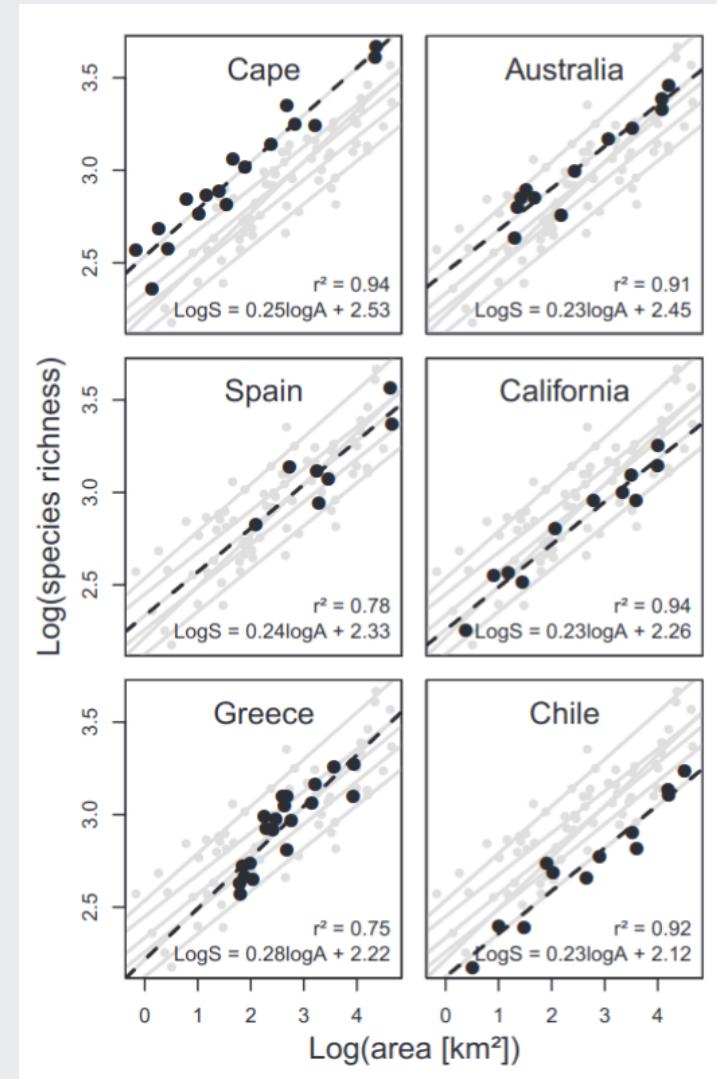


# Extinction and stability



Major change can be bad for diversity though... Too much, and things go extinct!

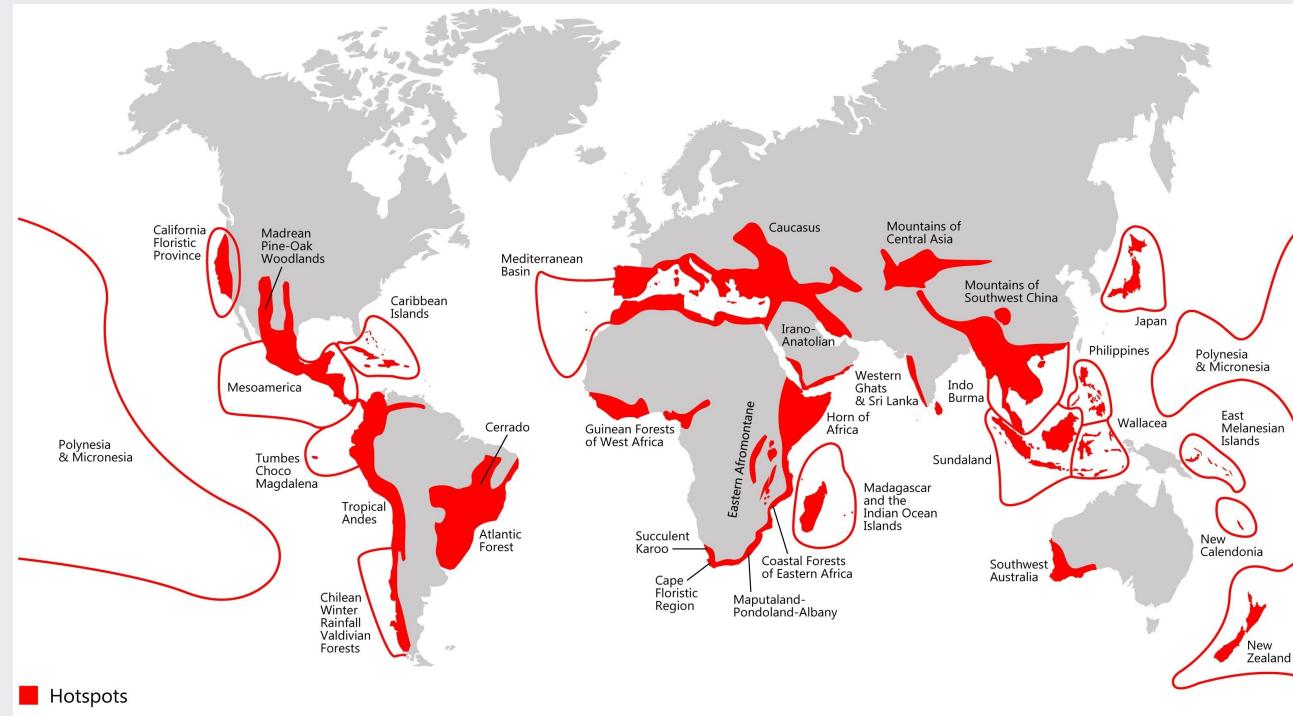
Environmental stability is key for maintaining high diversity, as evidences in the Med-Type Ecosystems of the world.



Cowling et al. 2015

# Extinction and stability

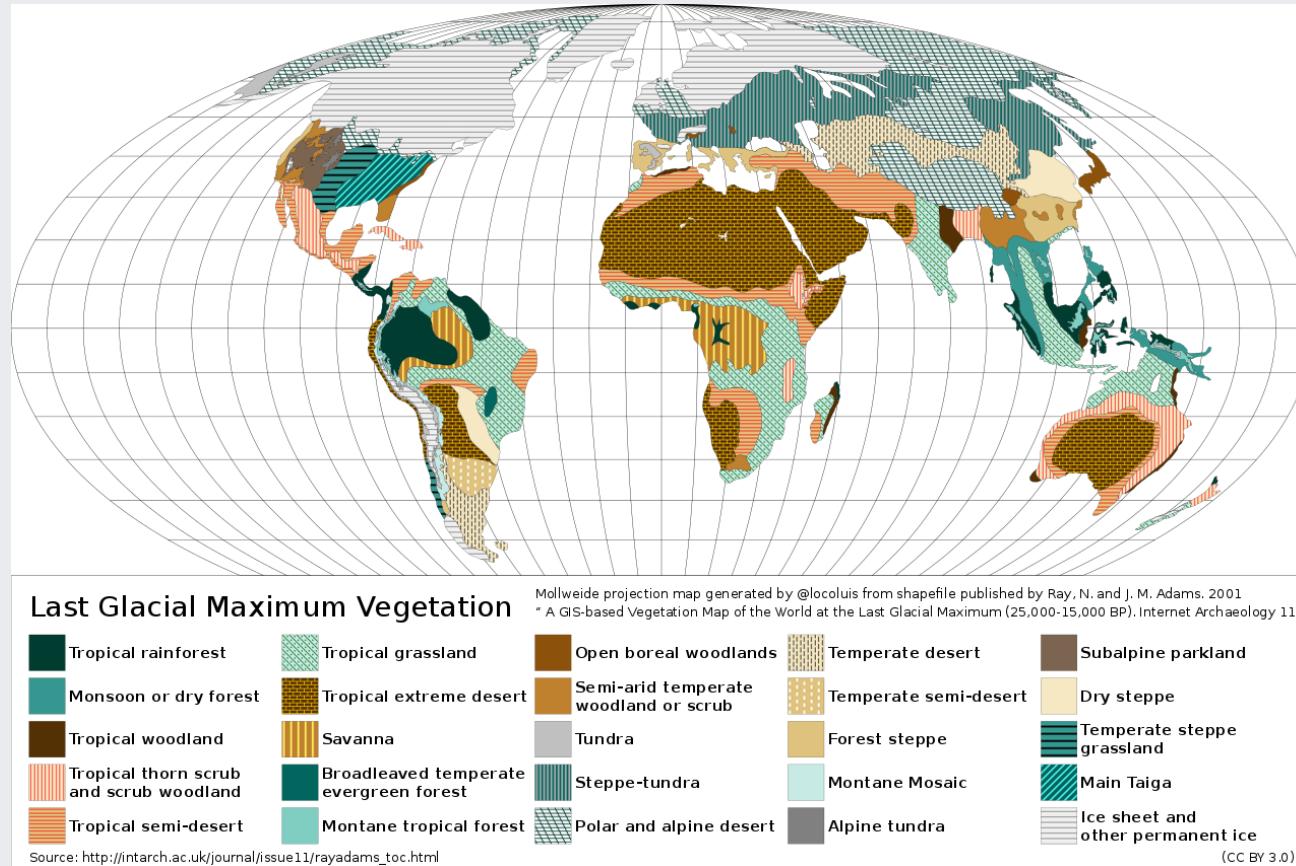
Why are there no biodiversity hotspots in the northern latitudes?



<https://www.conservation.org/priorities/biodiversity-hotspots>

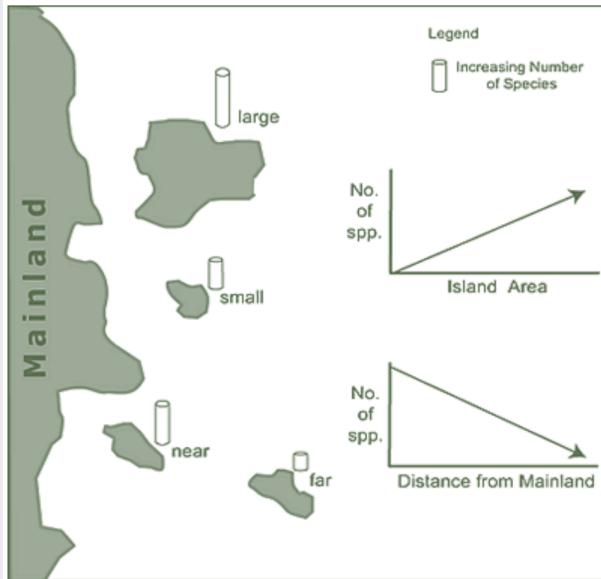
# Extinction and stability

They were mostly buried in ice 15-25 000 years ago!!!



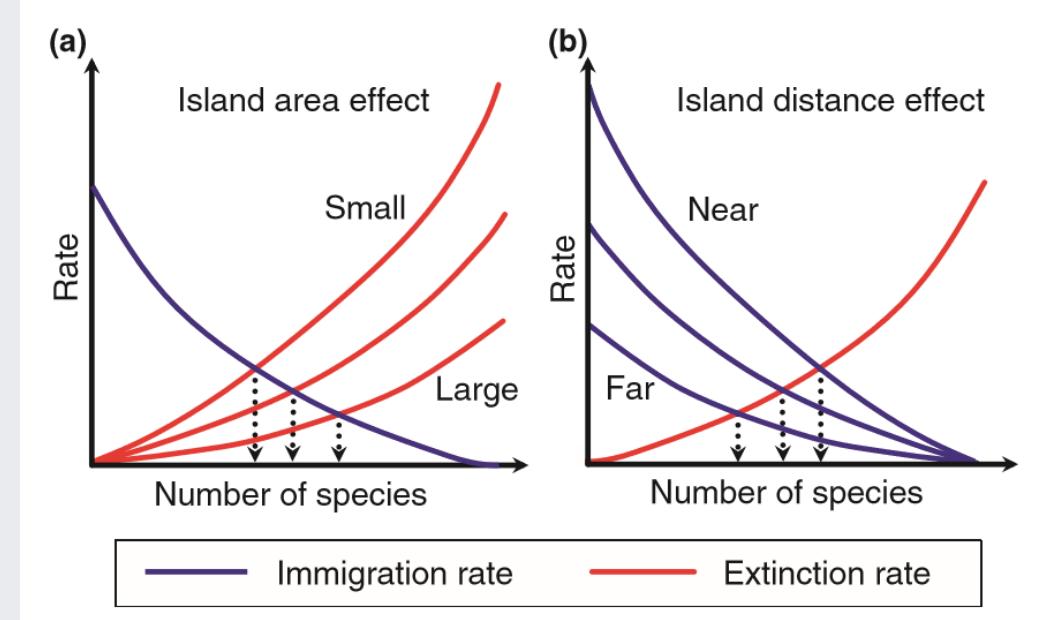
# Dispersal (and extinction)

## The Equilibrium Theory of Island Biogeography



Larger islands, closer to the mainland have more species.

- Larger = lower extinction (larger populations)
- Closer = higher immigration



An extension of IBT is to consider specific habitats as islands in a sea of unfavourable habitat (e.g. forest fragments in Fynbos).

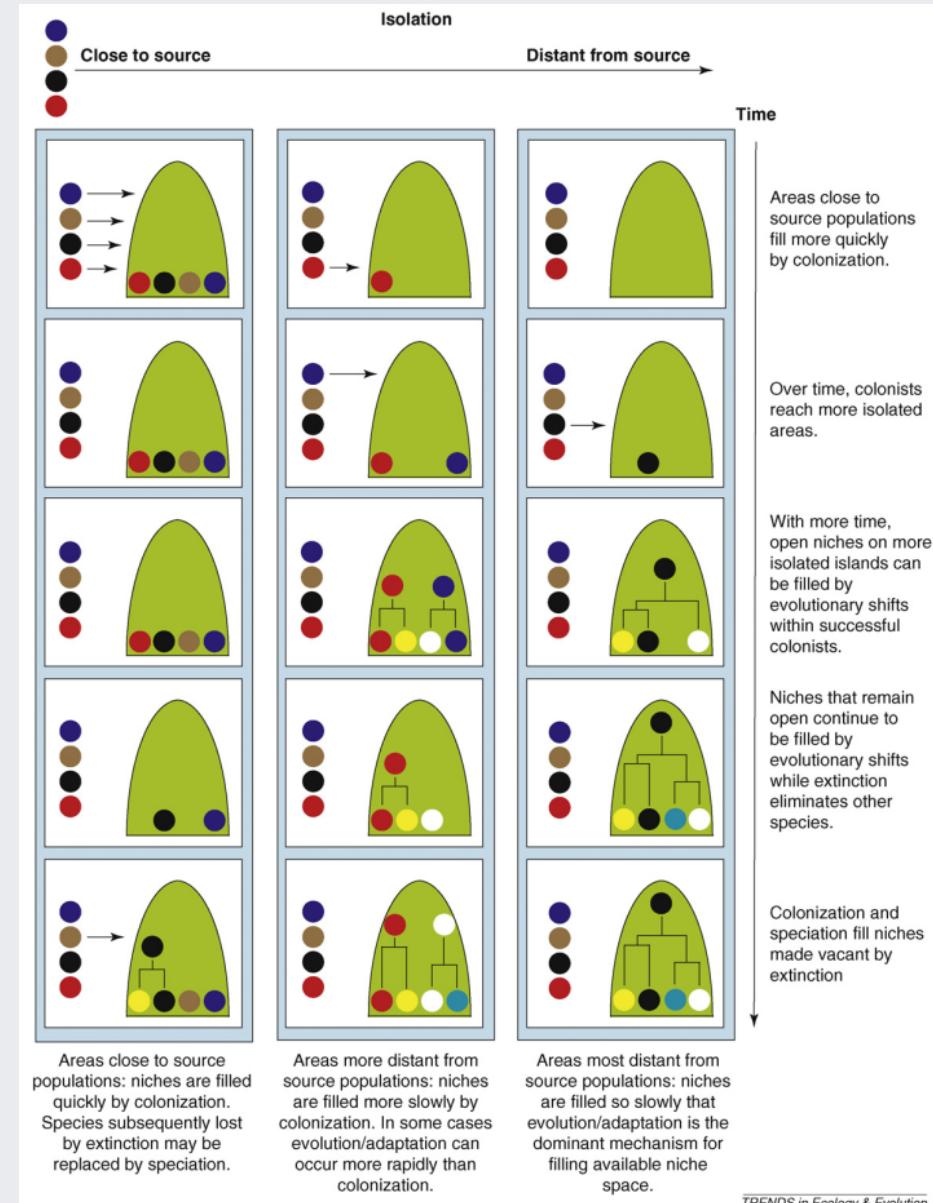
MacArthur and Wilson 1967 (Figure from Warren et al. 2015)

# Dispersal and speciation

## Island Biogeography Extended

Better connected islands/habitats are likely to be dominated by colonization, leaving little opportunity (niche space) for *in situ* speciation

Isolated islands/habitats where immigration is rare are likely to see local adaptation and *in situ* speciation over time, resulting in a community of close relatives

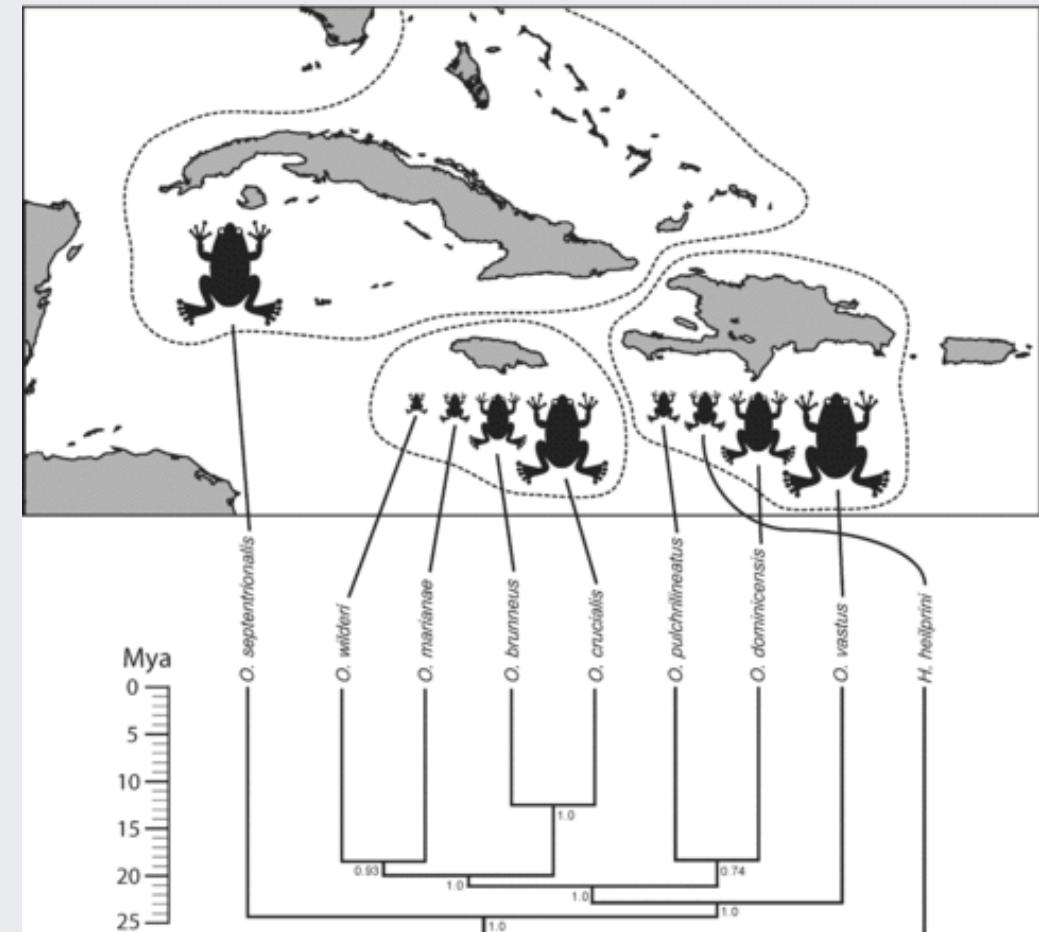
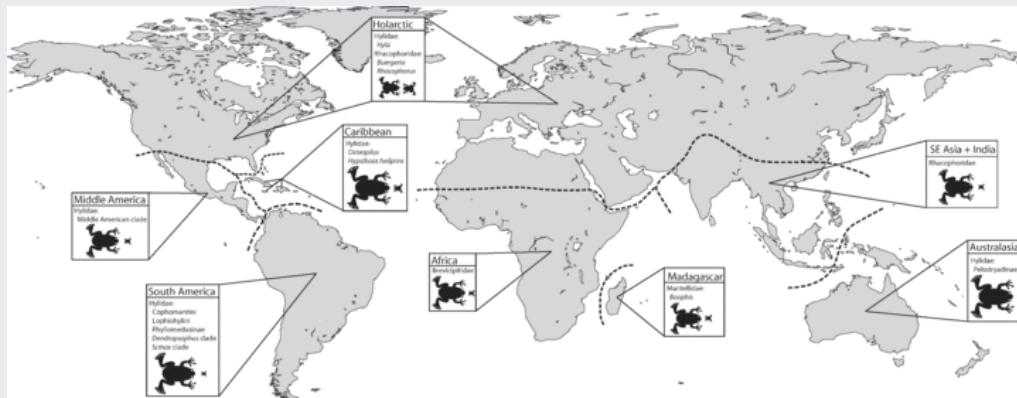


Emerson and Gillespie 2008

# Dispersal and speciation

## Island Biogeography Extended

Treefrog assemblages around the world have convergently evolved species with very large and small body sizes, representing resource partitioning, because prey size is associated with body size



This pattern is repeated at finer scales, such as islands in the Caribbean.

Moen and Wiens 2009

# Environmental heterogeneity

## A driver of diversity across scales?

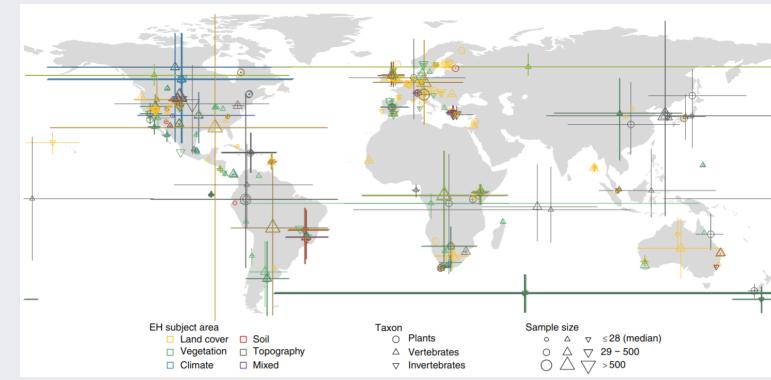
The Environmental Heterogeneity (EH) hypothesis  
(Ricklefs 1977 and others)

### Ecological (~local):

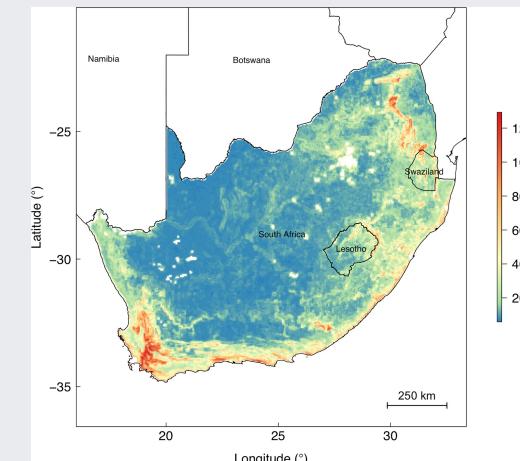
- Provides greater available niche space (and/or refuges), enhancing coexistence

### Evolutionary (~regional):

- Provides more opportunities for isolation and divergent adaptation, promoting diversification (speciation) and persistence (less extinction)



A meta-analysis of different taxa across the globe found strong support for EH (Stein et al. 2014).



Cramer and Verboom 2017 found good support for EH explaining plant diversity across South Africa.

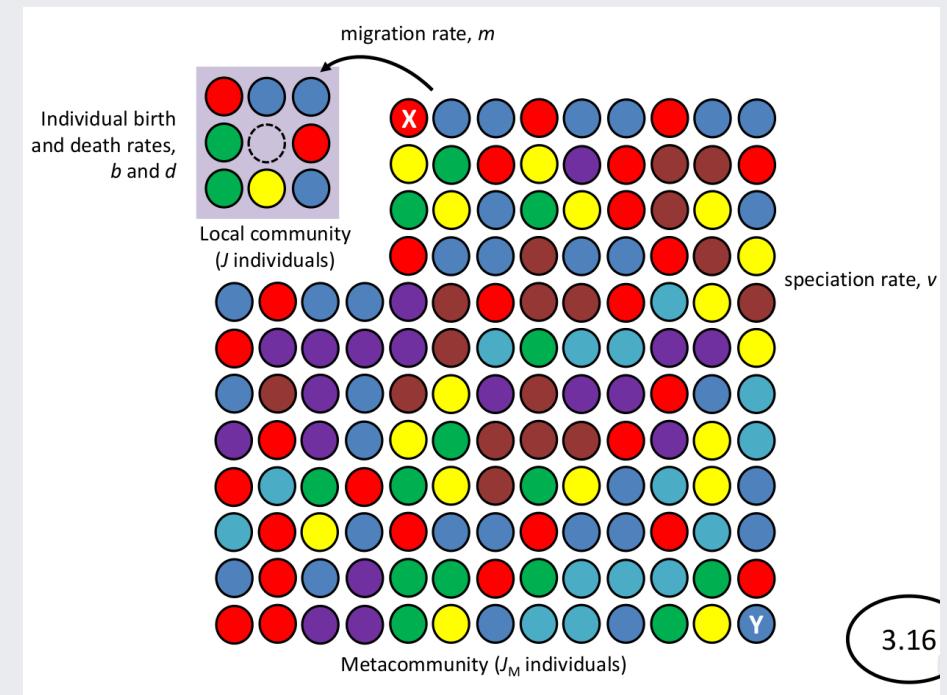
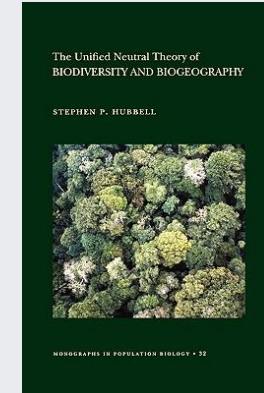
# "Neutral" models

*The Unified Neutral Theory of Biodiversity and Biogeography - Hubbell 2001*

All individuals of all species are functionally equivalent and local processes (competition etc) are mostly irrelevant... (i.e. only regional processes apply)

Local communities are determined by birth, death and migration, which depend only on species abundances...

Local patterns of functional and phylogenetic diversity are determined by the regional species pool (the "Metacommunity" in this case) and dispersal constraints...

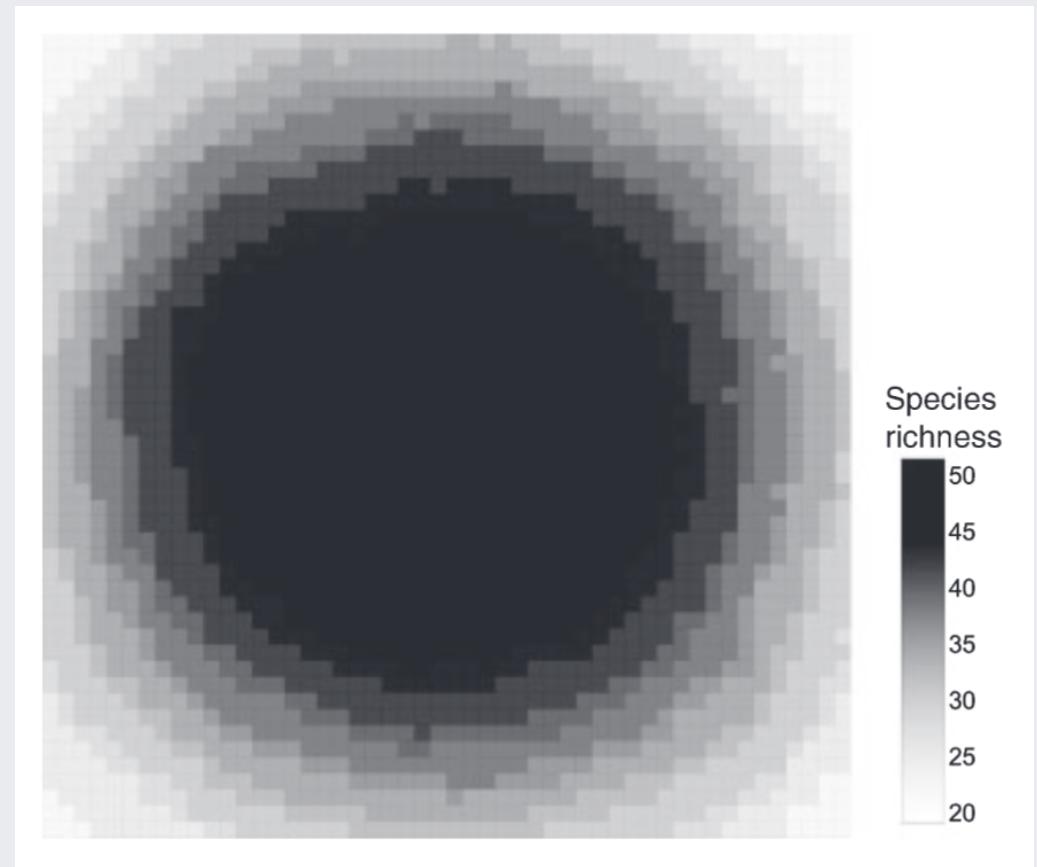


# "Neutral" models

The Mid-Domain Effect (MDE), Colwell & Lees 2000

- aims to explain spatial patterns in species richness invoking only stochasticity and geometrical constraints
- predicts a hump-shaped pattern in species richness in the mid-domain, because that's where most species ranges will overlap (if all else is equal, i.e. no ecological effects)
- it's essentially a spatially bounded neutral model where communities are linked by short-distance migration

Neutral models generally predict that local diversity is determined by regional processes...



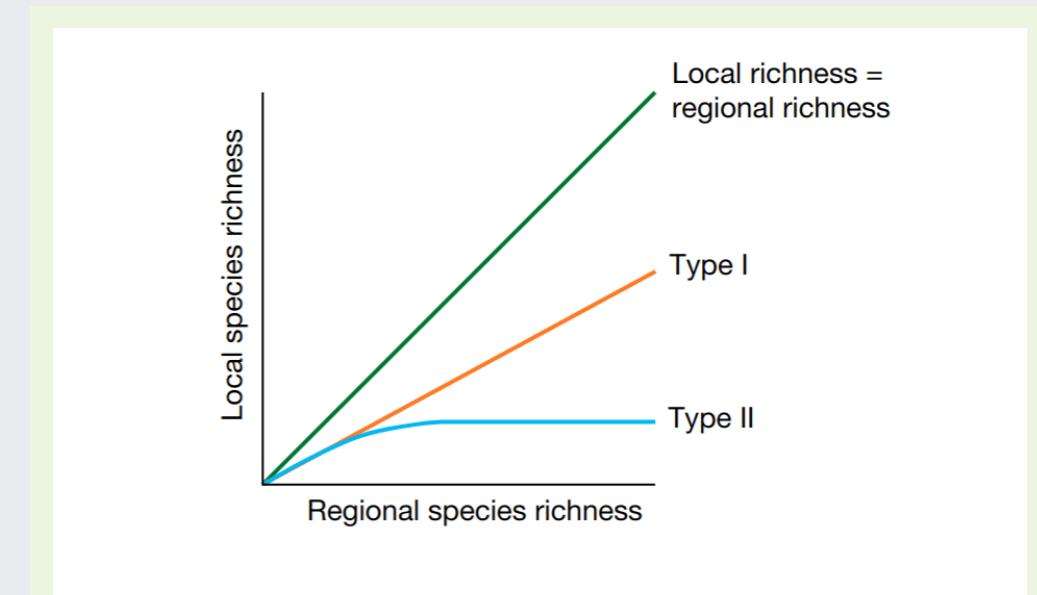
Rangel and Diniz-Filho 2005

# To what extent is variation in diversity the result of local determinism (i.e. ecology) vs regional processes (i.e. evolution and biogeography)?

Local determinism makes 3 predictions (Ricklefs 2004)

1. diversity should be strongly correlated with physical aspects of the environment
  - see EH hypothesis
2. local diversity in comparable habitats should not vary between regions
  - see Stability slides, comparing MTEs
3. local diversity, above some saturation level, should be independent of regional diversity
  - Type I = local diversity  $\propto$  regional diversity
  - Type II = local diversity saturates (i.e. because niche space is full...)

There is evidence for and against each, suggesting that the patterns we see are a mix of the two...



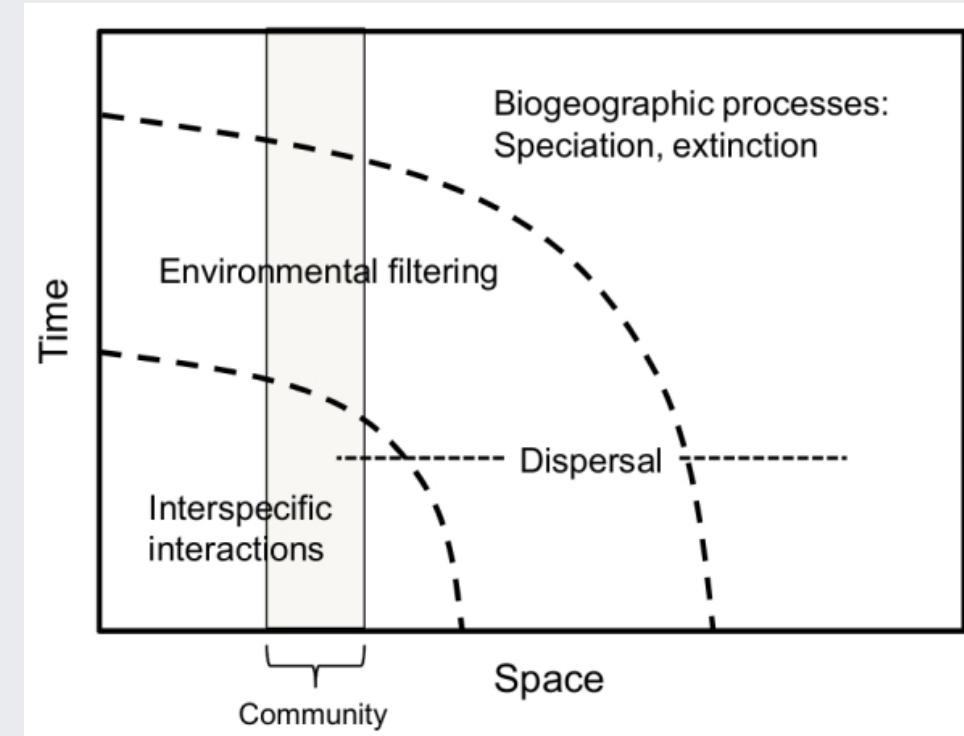
**Figure 3** Relations between local and regional species richness, illustrating the form of type I and type II relationships and the limiting condition where local richness equals regional richness.

Gaston 2000

# Community assembly processes

While processes vary with spatial or temporal scale,  
the distinction is somewhat arbitrary

- local patterns are affected by regional processes
- regional patterns are affected by local processes
- ecology and evolution are intricately intertwined



## Take-home

Diversity patterns are influenced by a range of processes, which operate at various temporal and spatial scales.

Some are more local, operating in ecological time. Others are more regional, operating over evolutionary time.

There is a continuum, so it's not straightforward to distinguish the ecological from the evolutionary.

Ecology and evolution are intricately intertwined. It's not advisable to study either without cognisance of the other.

# References

- Gotelli, N. J. and R. K. Colwell (2001). "Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness". In: *Ecology letters* 4.4, pp. 379-391. ISSN: 1461-023X, 1461-0248. DOI: 10.1046/j.1461-0248.2001.00230.x.
- Slingsby, J. A., C. Merow, M. Aiello-Lammens, et al. (2017). "Intensifying postfire weather and biological invasion drive species loss in a Mediterranean-type biodiversity hotspot". En. In: *Proceedings of the National Academy of Sciences of the United States of America* 114.18, pp. 4697-4702. ISSN: 0027-8424, 1091-6490. DOI: 10.1073/pnas.1619014114.
- Whittaker, R. H. (1972). "Evolution and measurement of species diversity". En. In: *Taxon* 21.2-3, pp. 213-251. ISSN: 0040-0262, 1996-8175. DOI: 10.2307/1218190.

# Thanks!

Slides created via the R packages:

**xaringan**  
gadenbuie/xaringanthemer

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