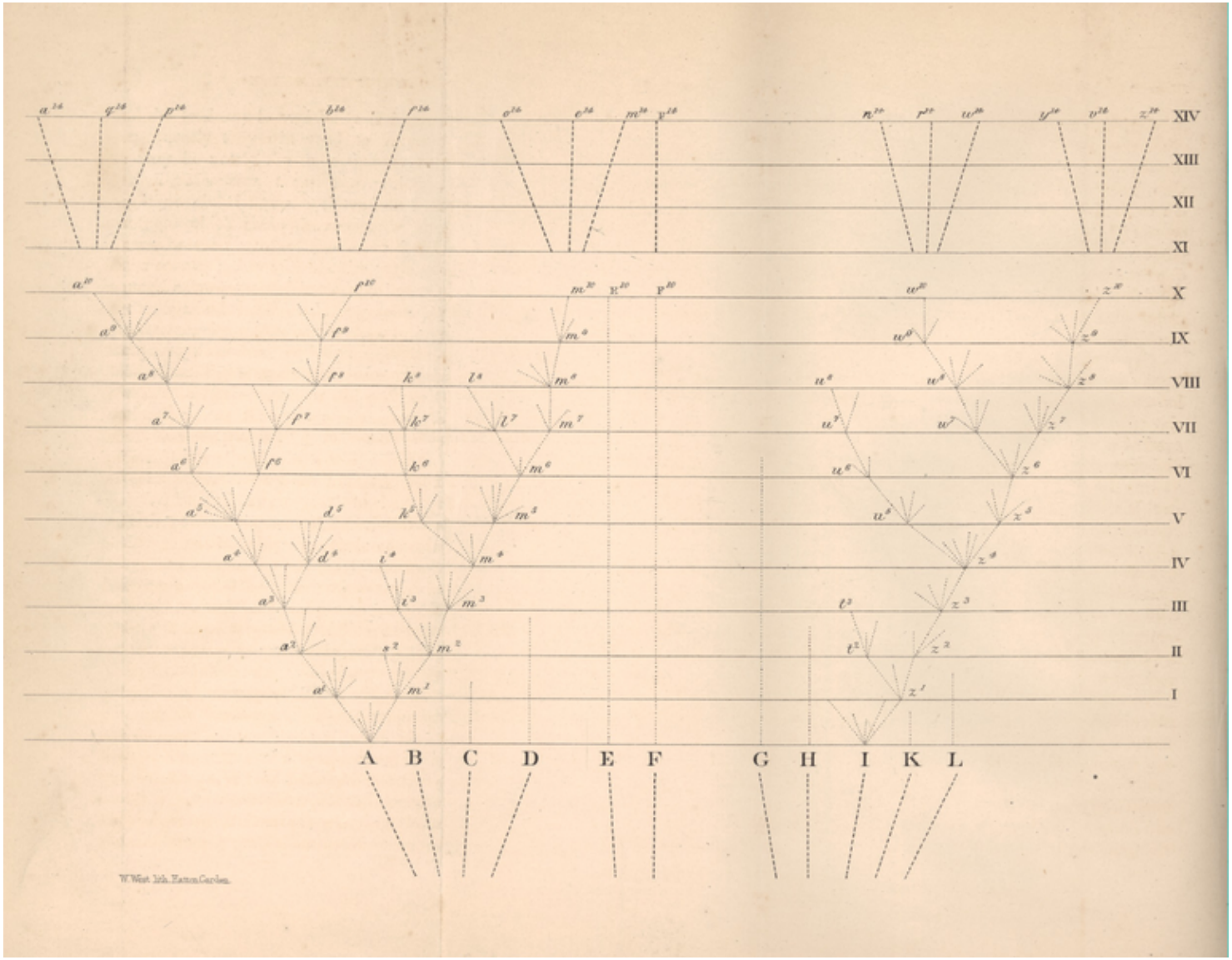
Phylogenetics and Communities



(from: Darwin, C. 1859. *The Origin of Species*. John Murray, Albermarle St., London.)

Phylogenetics and Communities

Overview of this section:

1) Basic Phylogenetics

2) Phylogenetic reconstructions and vicariance

3) Phylogeography

4) Phylogenetic community structure

a) overview and basic concepts

- phylogenetic patterns in community composition

- overview of diversity metrics

- observations of species distributions along environmental gradients

b) application to Andean bird communities

Phylogenetics and Communities

The first formal (and most comprehensive) development of community phylogenetics by Campbell Webb and colleagues in 2002

Proposed that "studies in community ecology can be informed by knowledge of the evolutionary relationships among coexisting species"

1) Examining the phylogenetic structure of community assemblages
2) Exploring the phylogenetic basis of community niche structure
3) Adding a community context to studies of trait evolution and biogeography

PHYLOGENIES AND COMMUNITY ECOLOGY

Campbell O. Webb[1], David D. Ackerly[2], Mark A. McPeek[3], and Michael J. Donoghue[1]

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[2]*Department of Biological Sciences, Stanford University, Stanford, California 94305; email: dackerly@stanford.edu*

[3]*Department of Biology, Dartmouth College, Hanover, New Hampshire 03755; email: mark.mcpeek@dartmouth.edu*

Phylogenetics and Communities

Phylogenetic community structure: the pattern of phylogenetic relatedness of species within and among communities

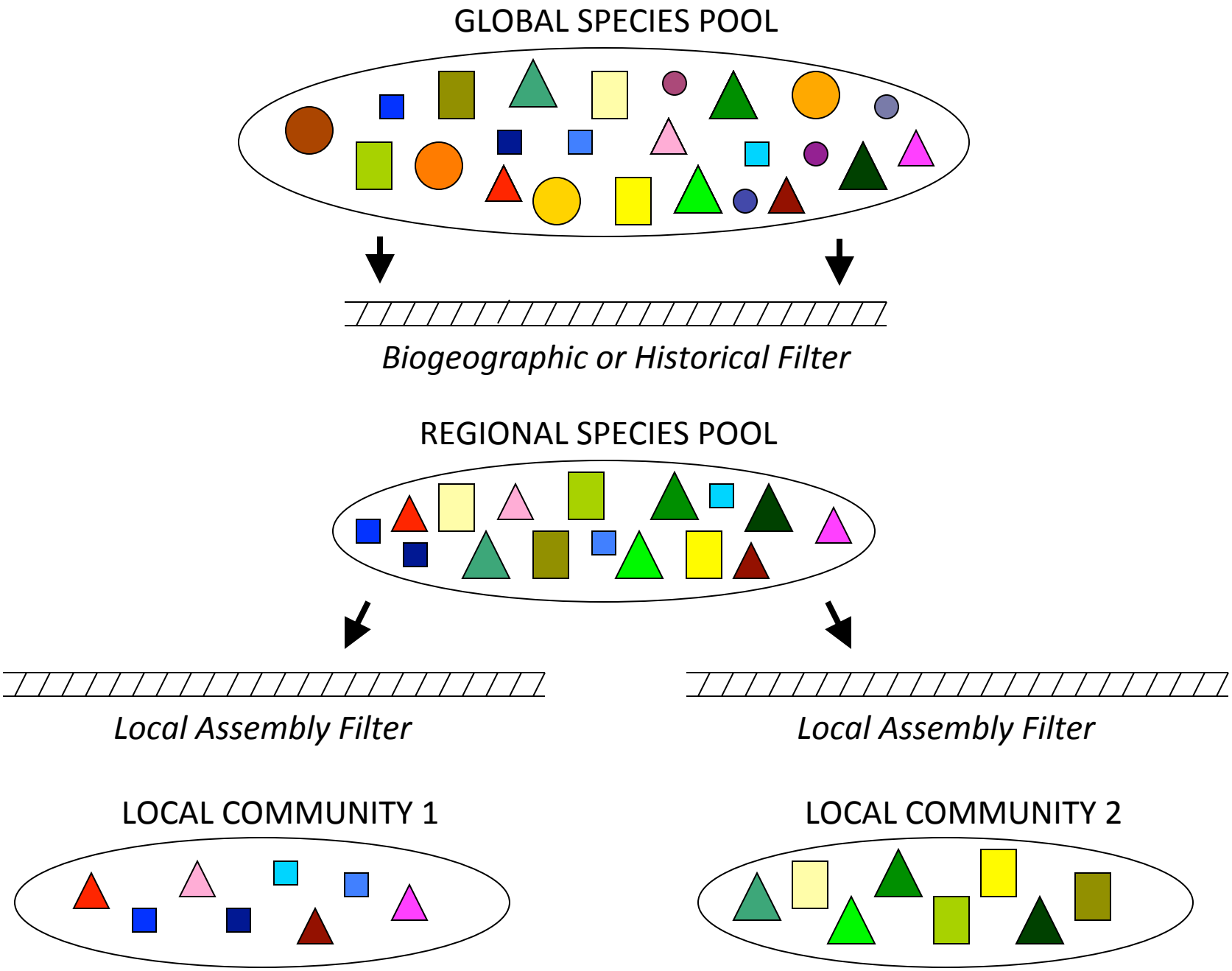
Phylogenetic community structure is examined using statistical tests to determine the extent to which species within ecological communities are more or less closely related than expected by chance.

Phylogenetically clustered = co-occurring species in communities are close relatives

Phylogenetically overdispersed (or 'even') = co-occurring species are less closely related

We can compare observed patterns to a null model = what would be expected if species in communities were found at random locations on a phylogenetic tree

(We'll look at these tests and terms with an example of Andean bird communities…)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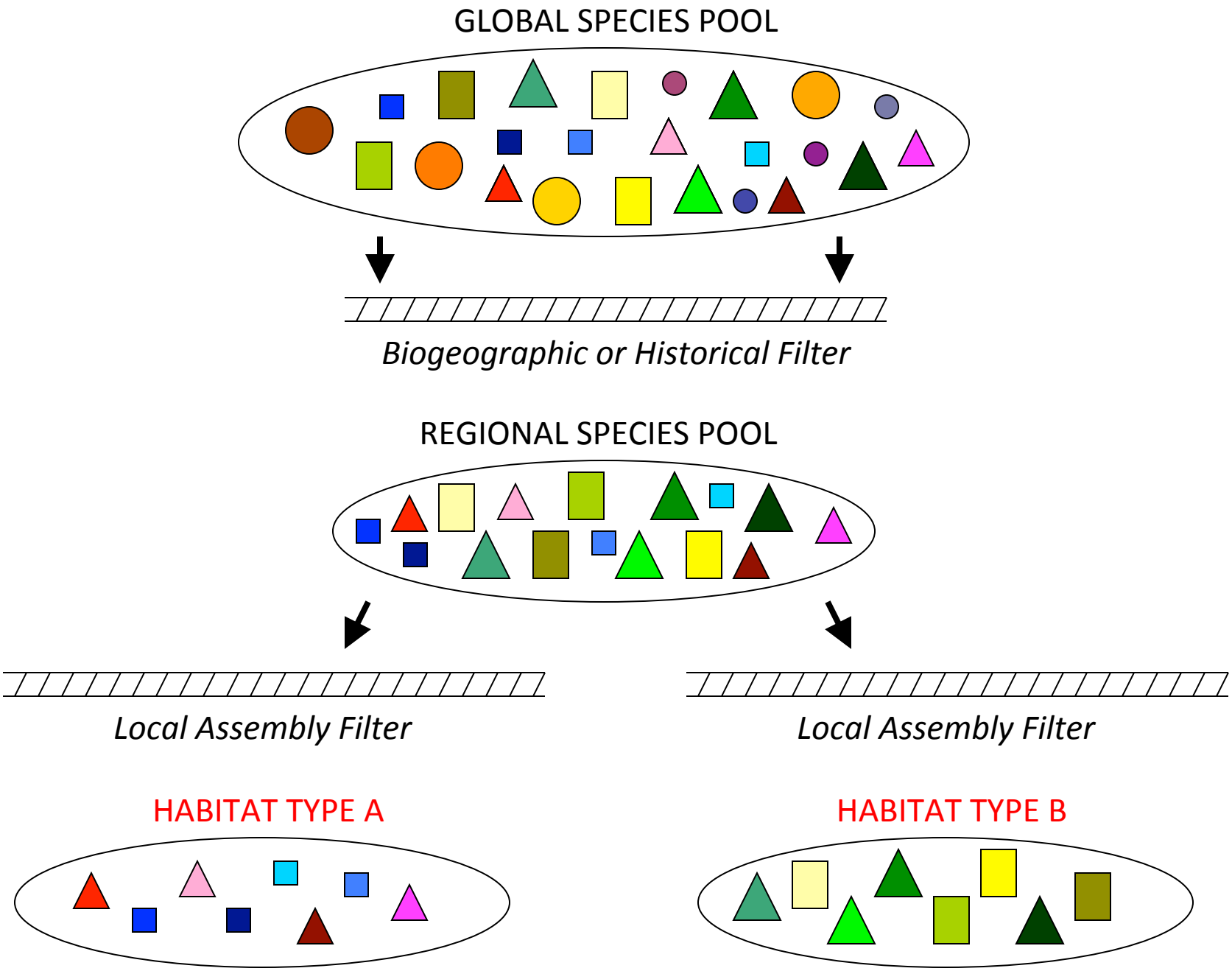
REGIONAL SPECIES POOL
Local Assembly Filter
Local Assembly Filter
LOCAL COMMUNITY 1
LOCAL COMMUNITY 2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Biogeographic or Historical Filter
REGIONAL SPECIES POOL
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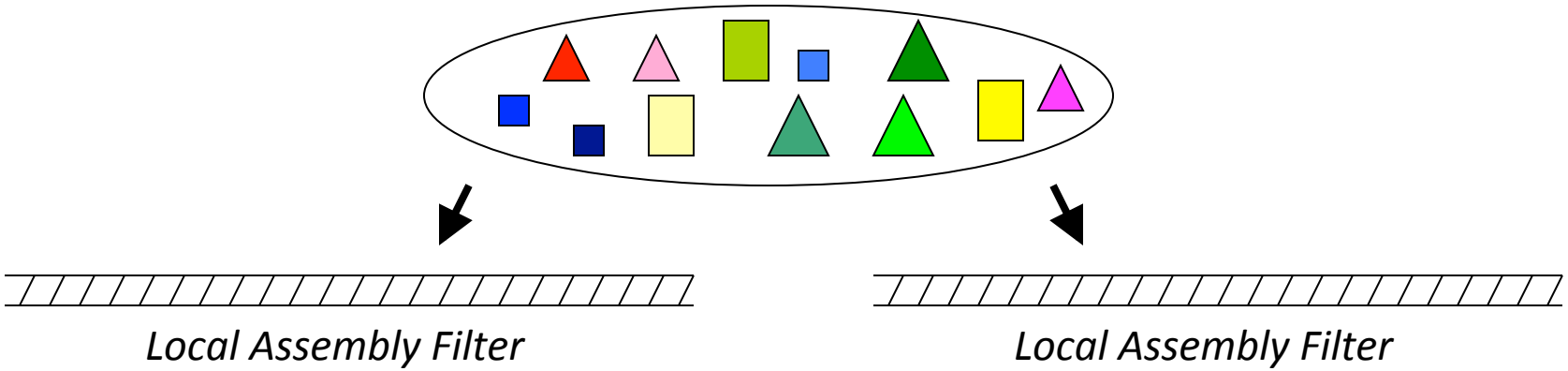
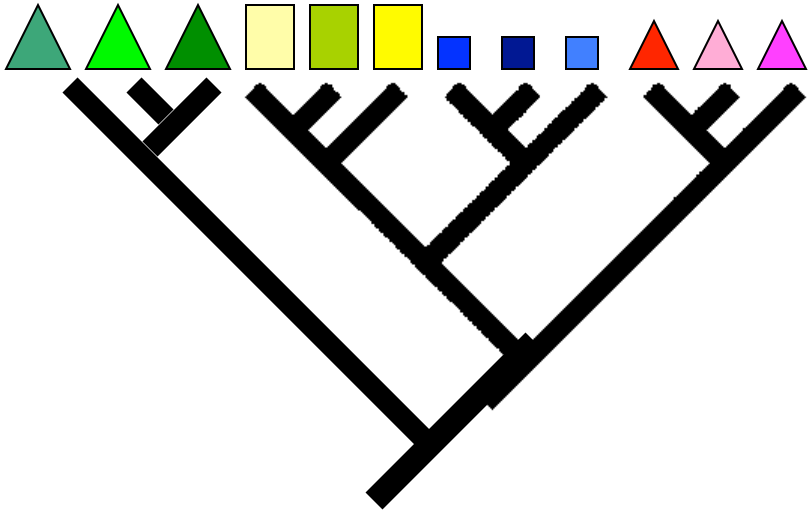
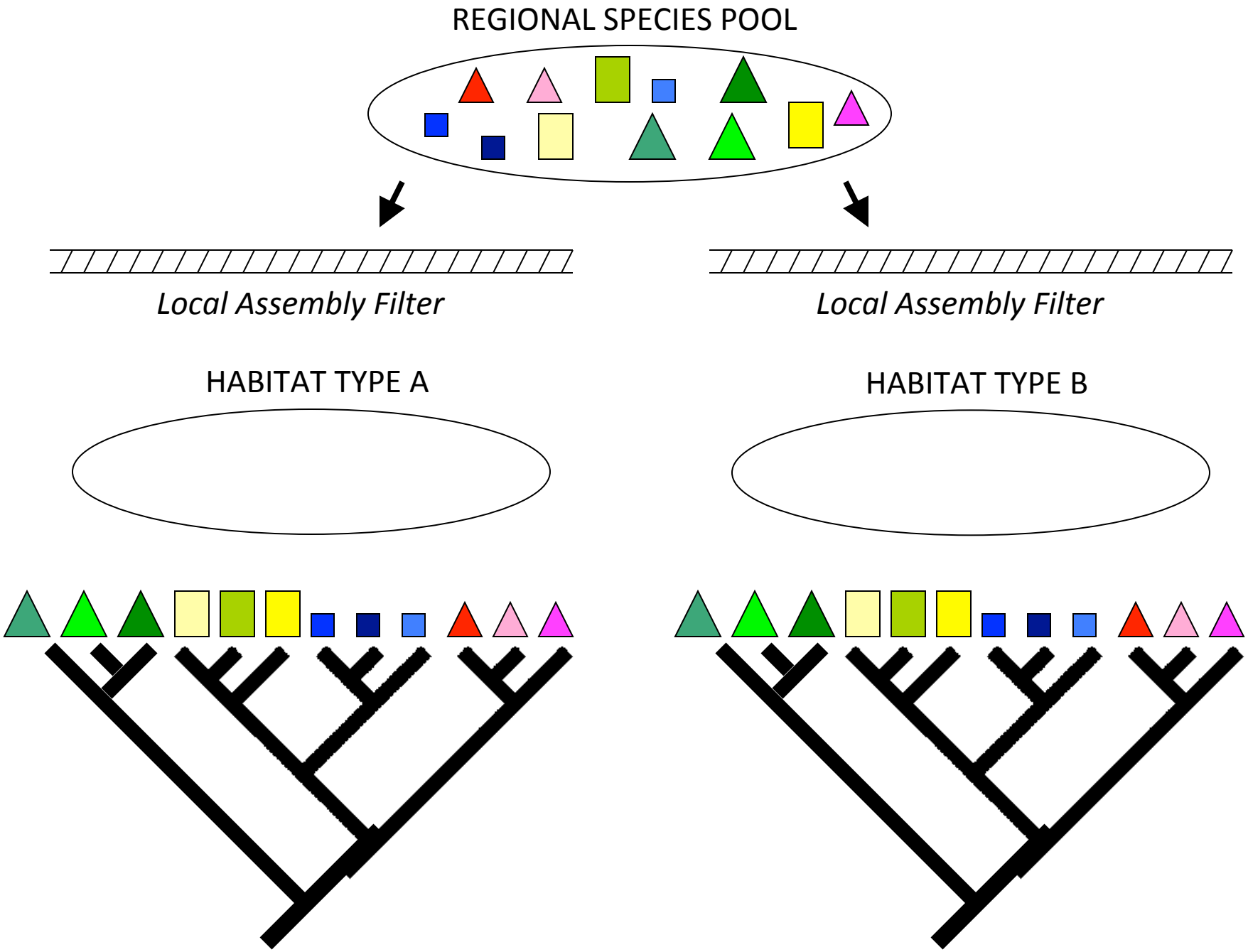
HABITAT TYPE B



How can a phylogeny help us to understand possible mechanisms influencing local community composition?

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Local Assembly Filter
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HABITAT TYPE A
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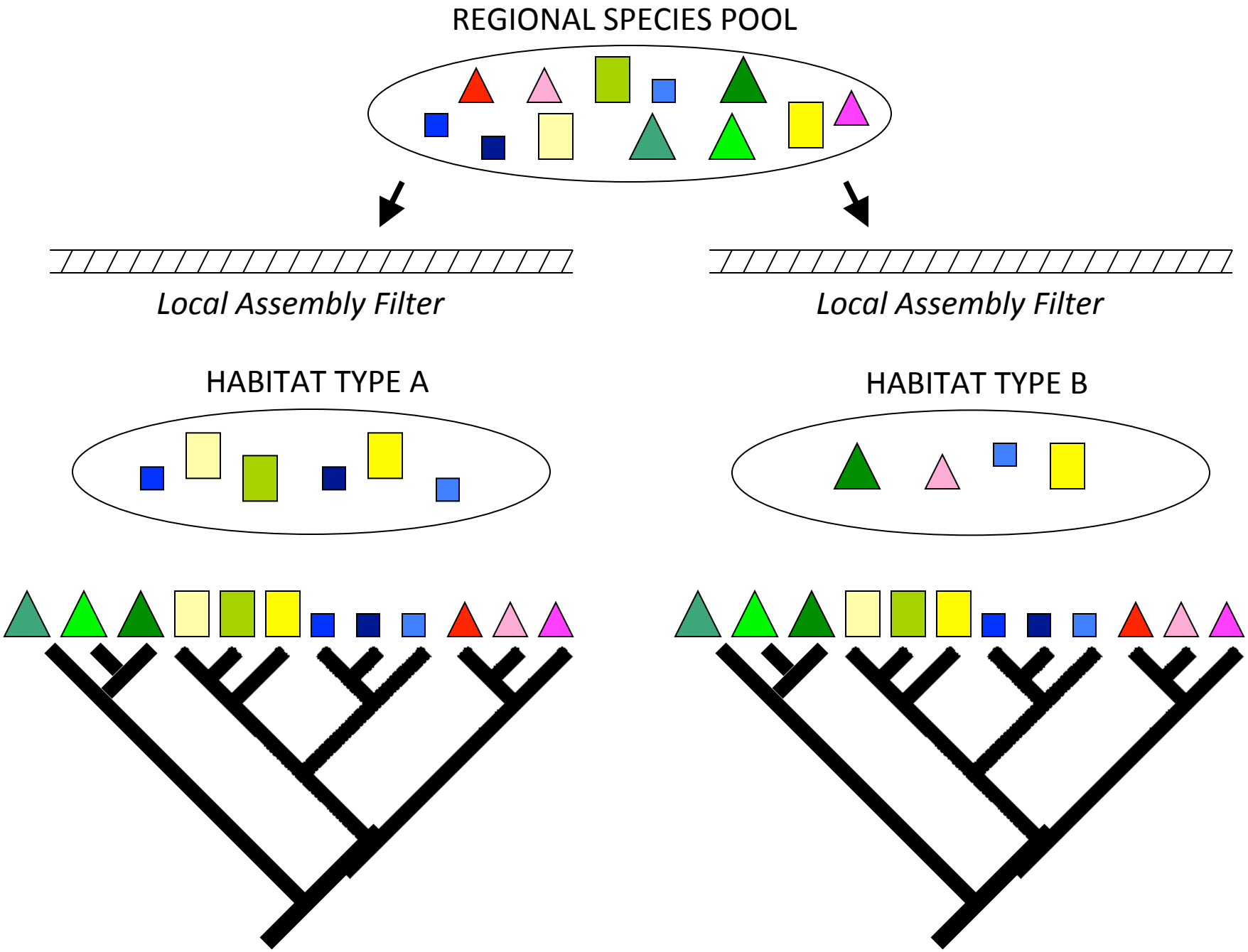
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Local Assembly Filter
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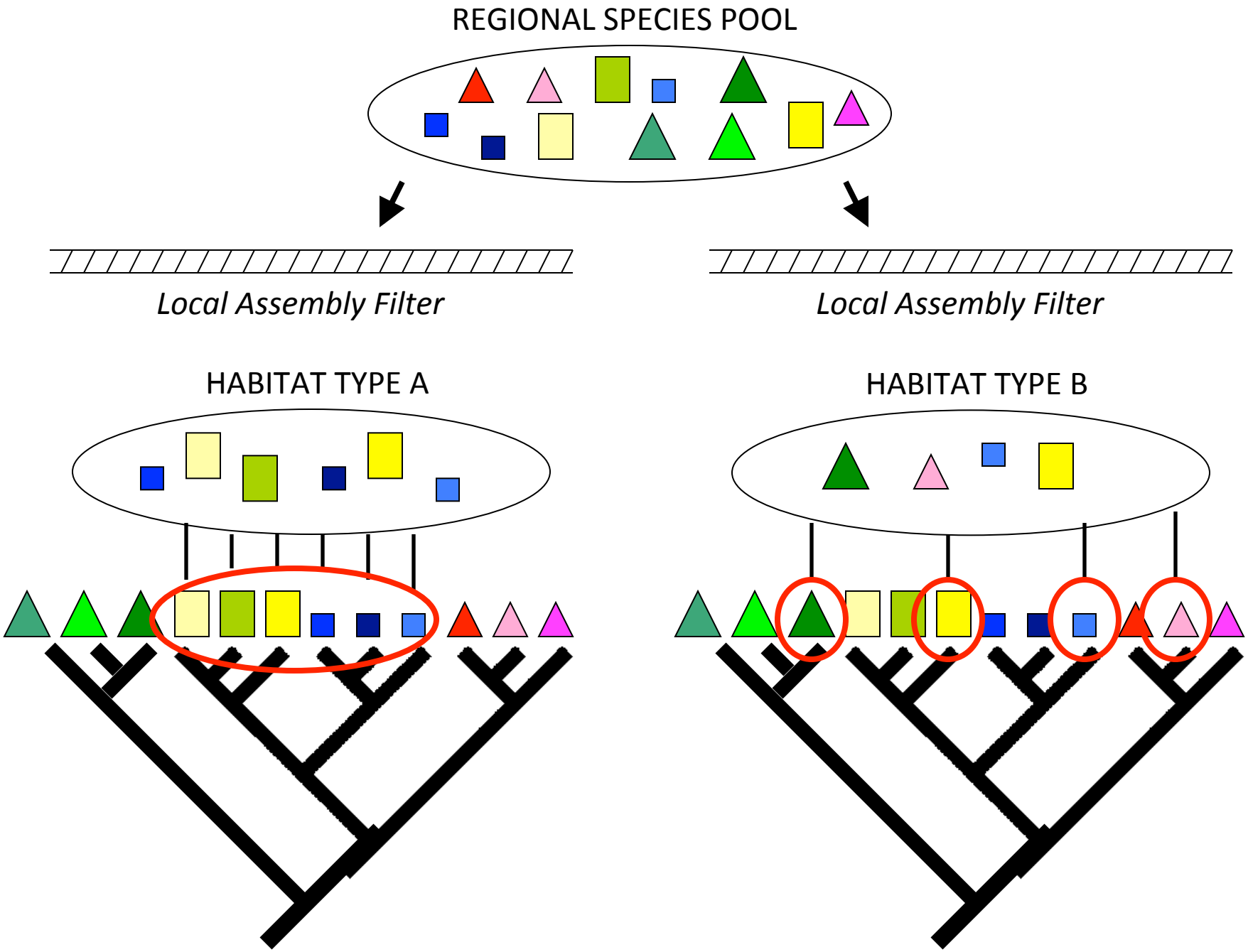
REGIONAL SPECIES POOL
Local Assembly Filter
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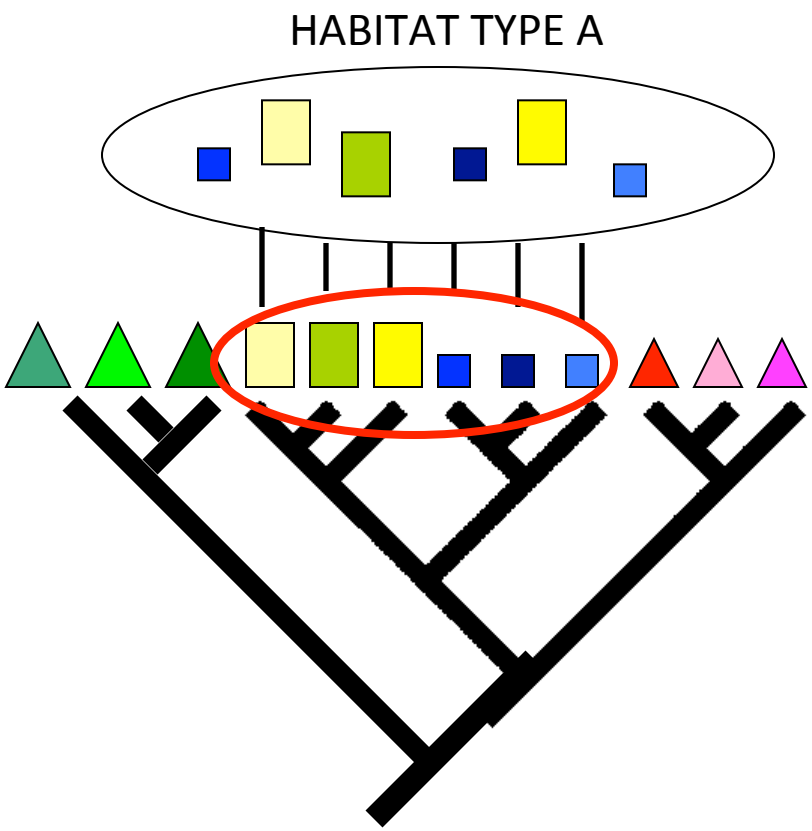
HABITAT TYPE A
HABITAT TYPE B

Phylogenetic patterns in communities

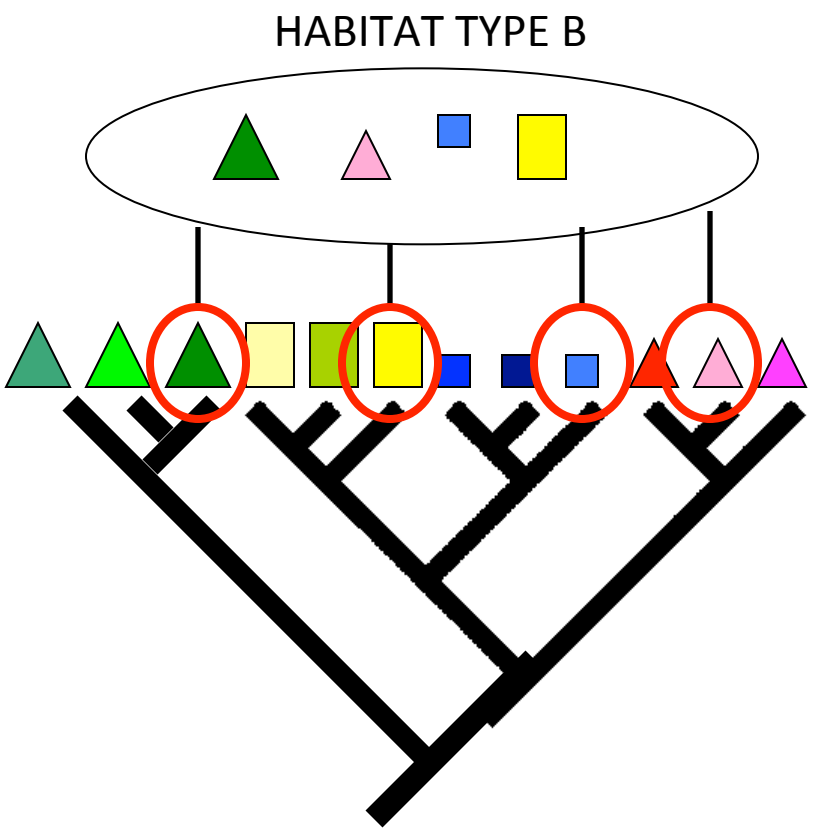
Phylogenetic Clustering

Species occurring in Habitat A are more closely related than expected by chance



Phylogenetic Evenness

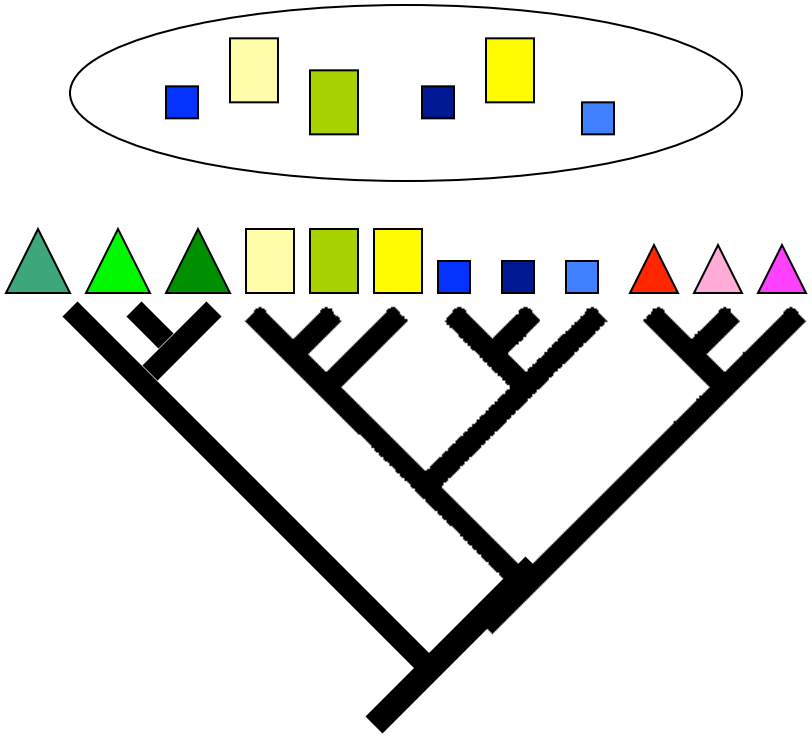
Species occurring in Habitat B are more distantly related than expected by chance



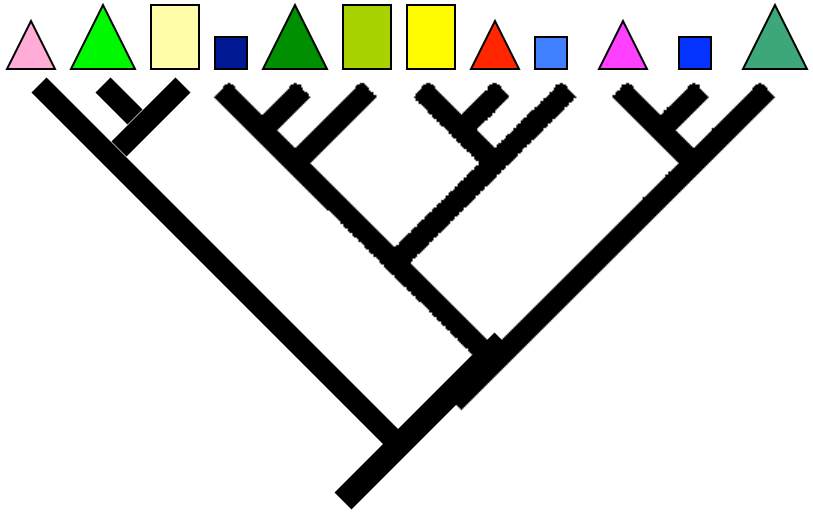
Measuring phylogenetic patterns in communities

Calculate **mean phylogenetic distance (MPD)** for all pairwise species combinations in local community

HABITAT TYPE A



Randomize placement of species on phylogeny and recalculate (1000's of times)



Measuring phylogenetic patterns in communities

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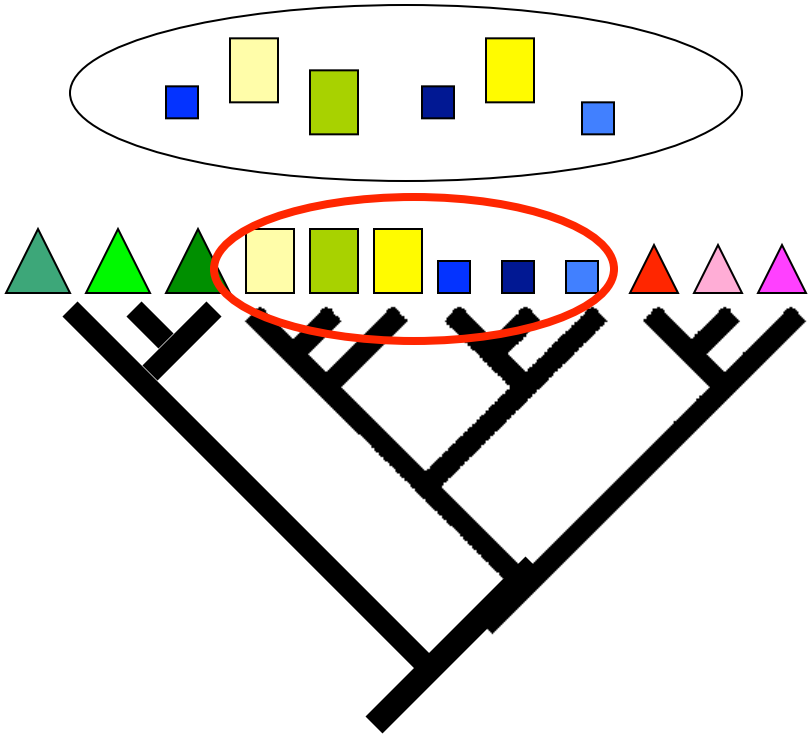

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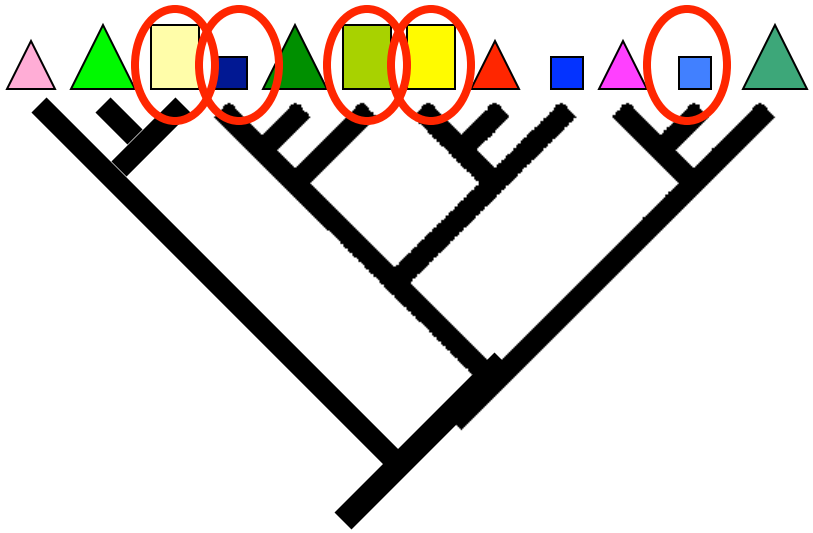

Measuring phylogenetic patterns in communities

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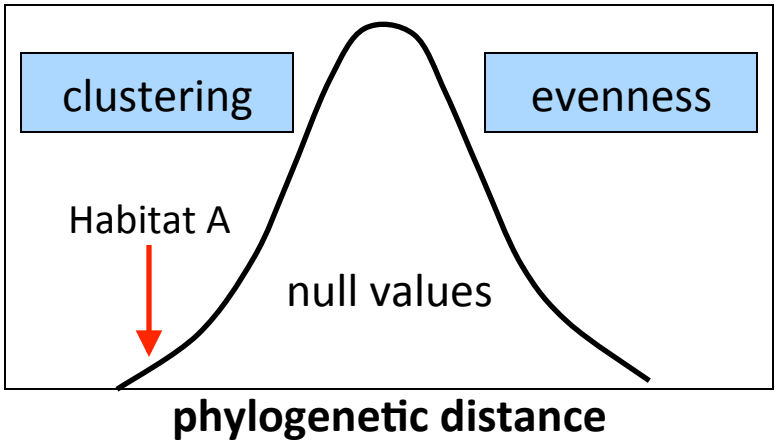
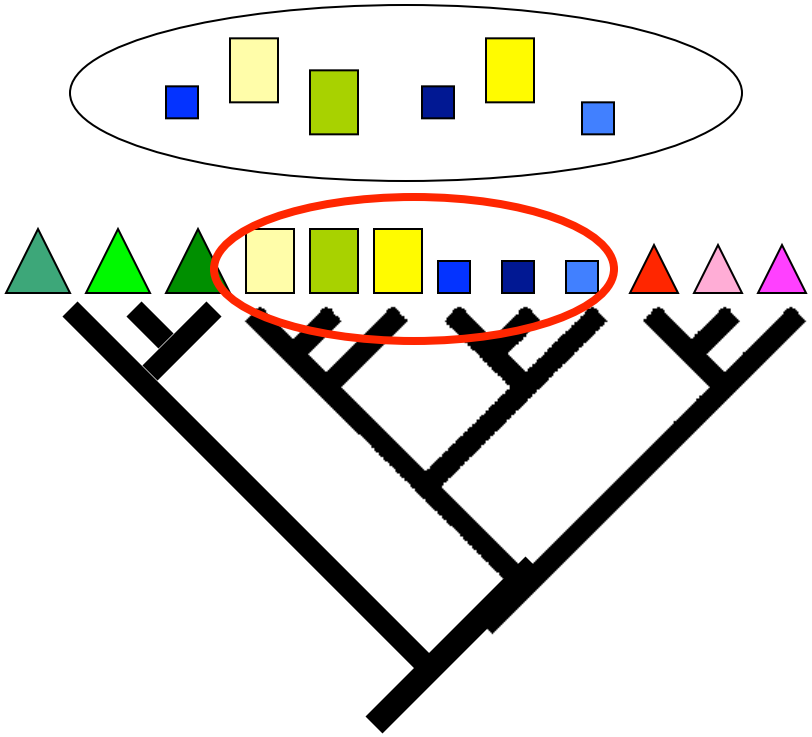


HABITAT TYPE A



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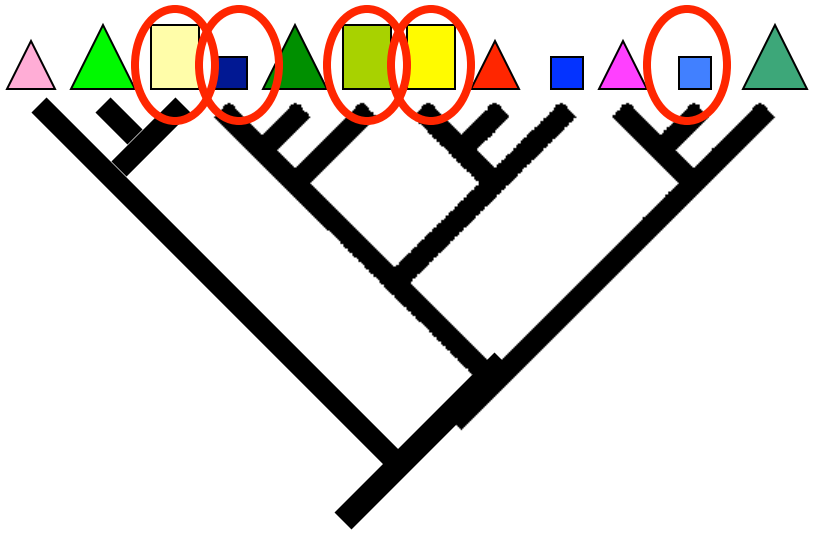
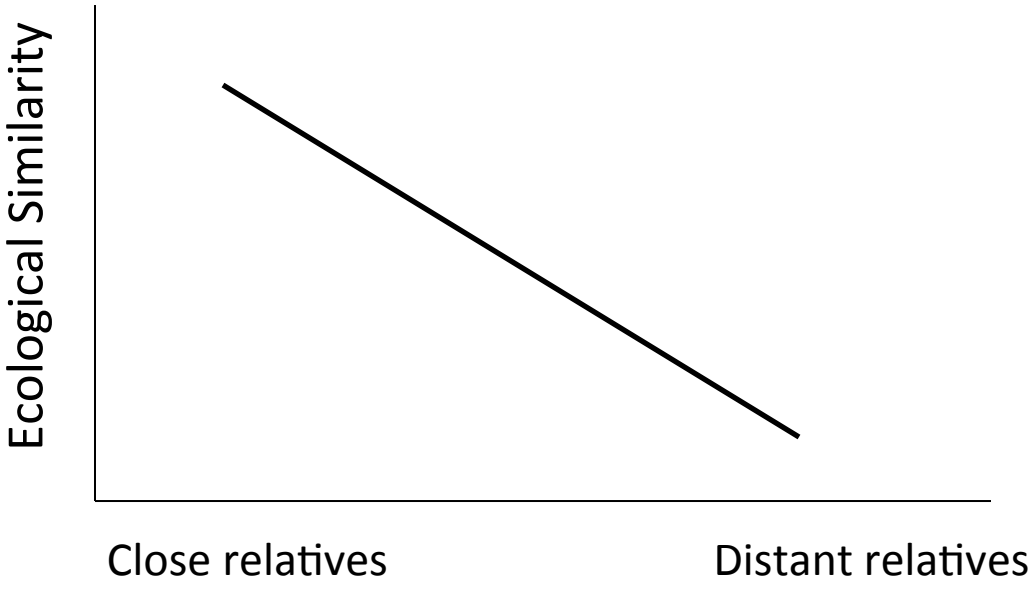


What do patterns of phylogenetic clustering or evenness mean for community assembly?

We may expect species' traits to be conserved
and for close relatives to be more ecologically similar:



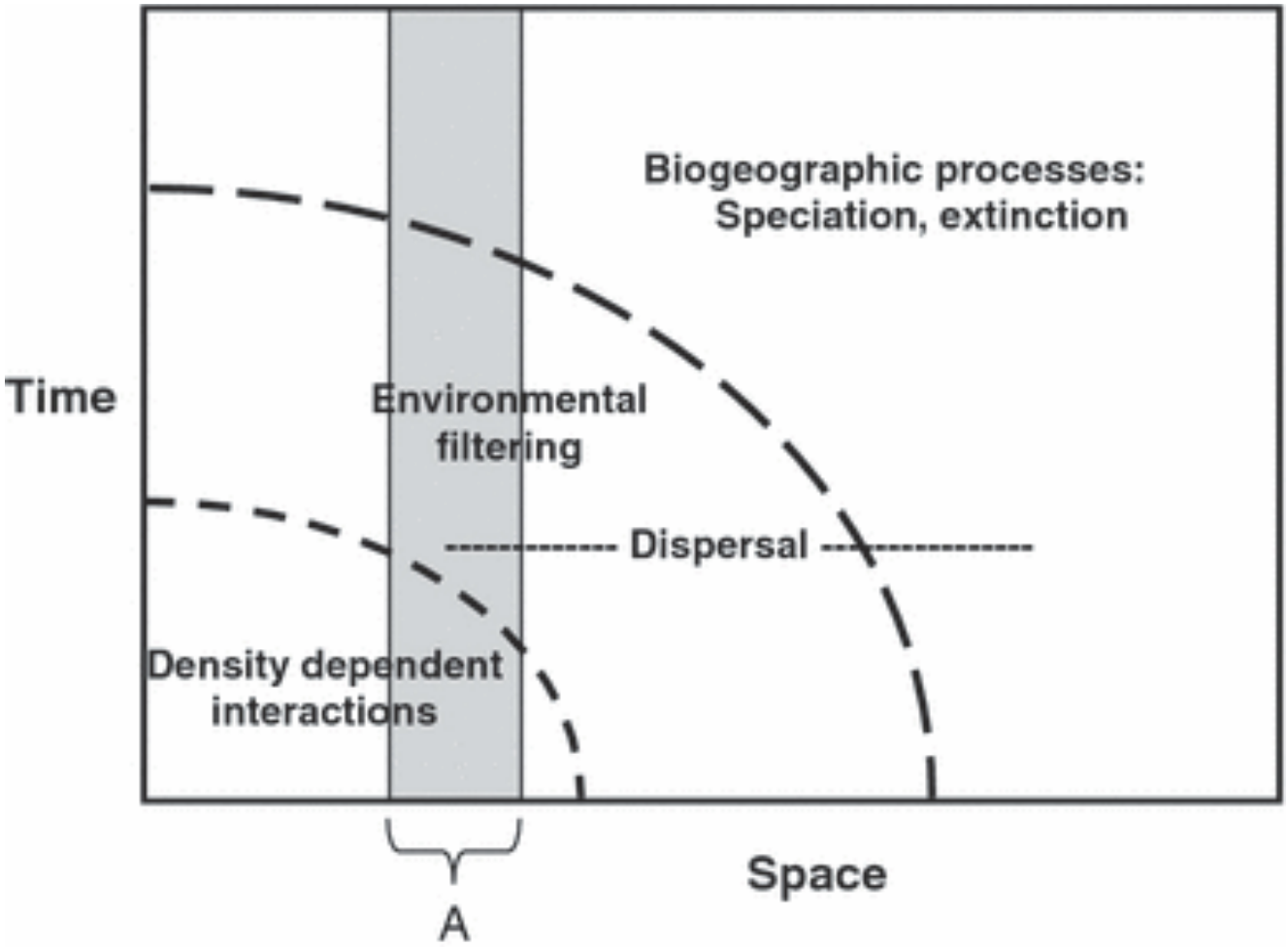
If traits are conserved…

Phylogenetic evenness:
interactions between close relatives prevent coexistence

Phylogenetic clustering:
close relatives share traits that allow persistence in environment

Phylogenetics and Communities

Determinants of species distributions vary across spatial and temporal scales



Dispersal varies with the mobility of the organism

Environmental filters can include both abiotic or biotic factors

Density-dependent interactions include competition, disease, predation, mutualism etc.

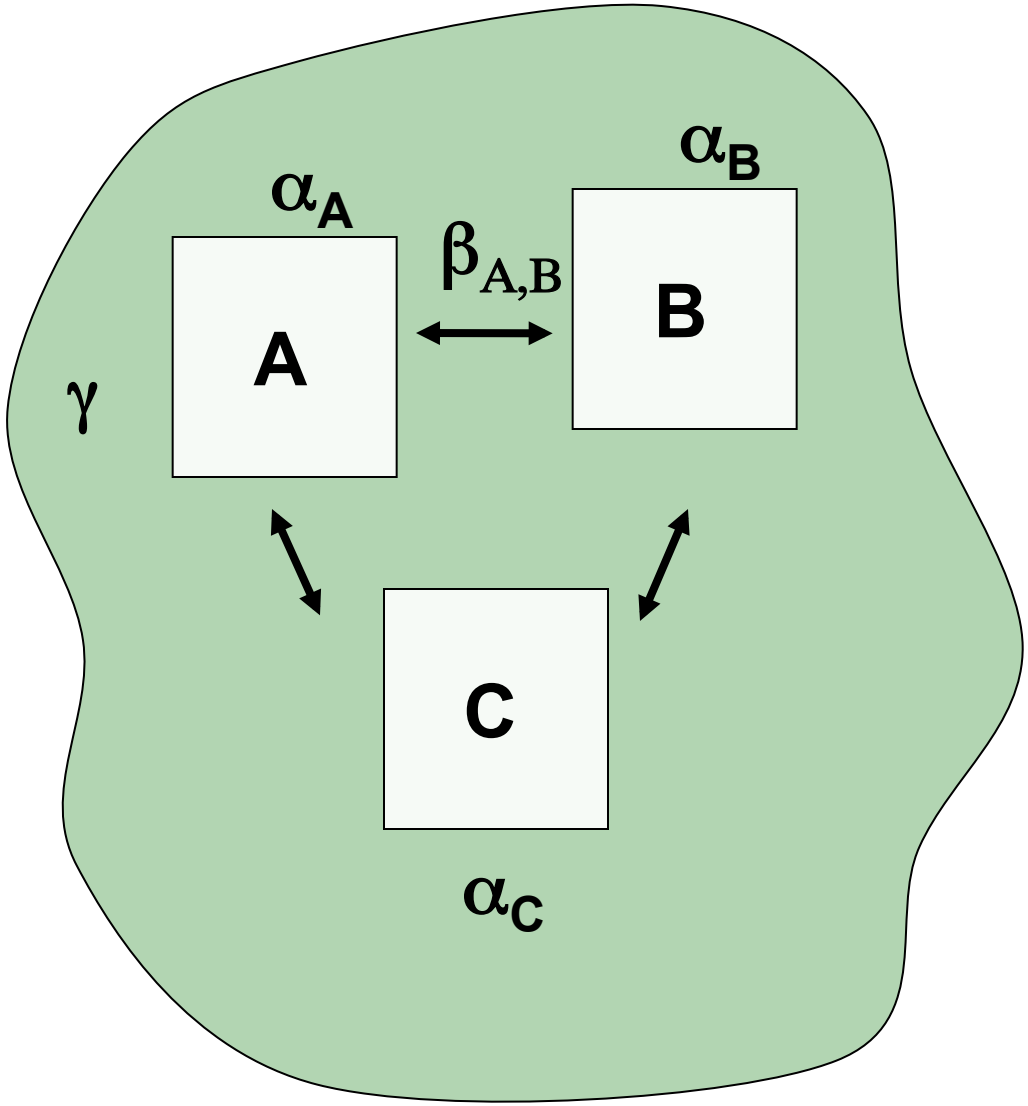
At any scale (A) species distributions depend upon multiple factors

Quantifying spatial components of diversity

Gamma (γ) diversity

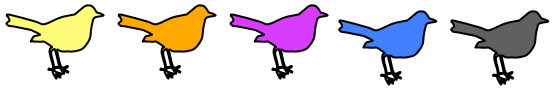
Alpha (α) diversity

Beta (β) diversity

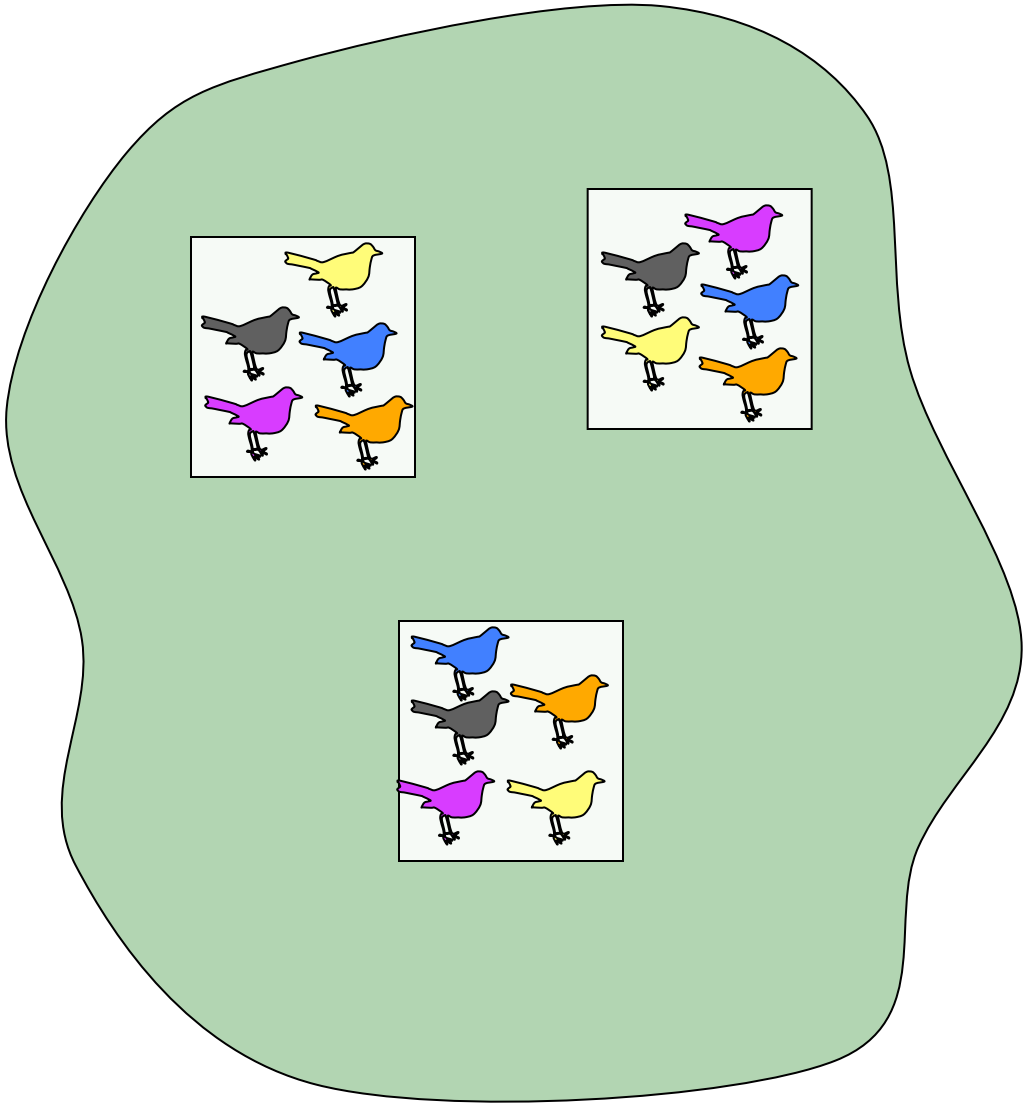


Quantifying spatial components of diversity

Regional pool (γ)

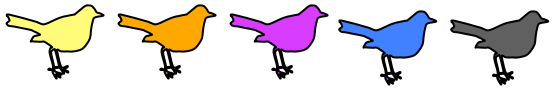


If α diversity ≅ γ diversity
→ low β diversity



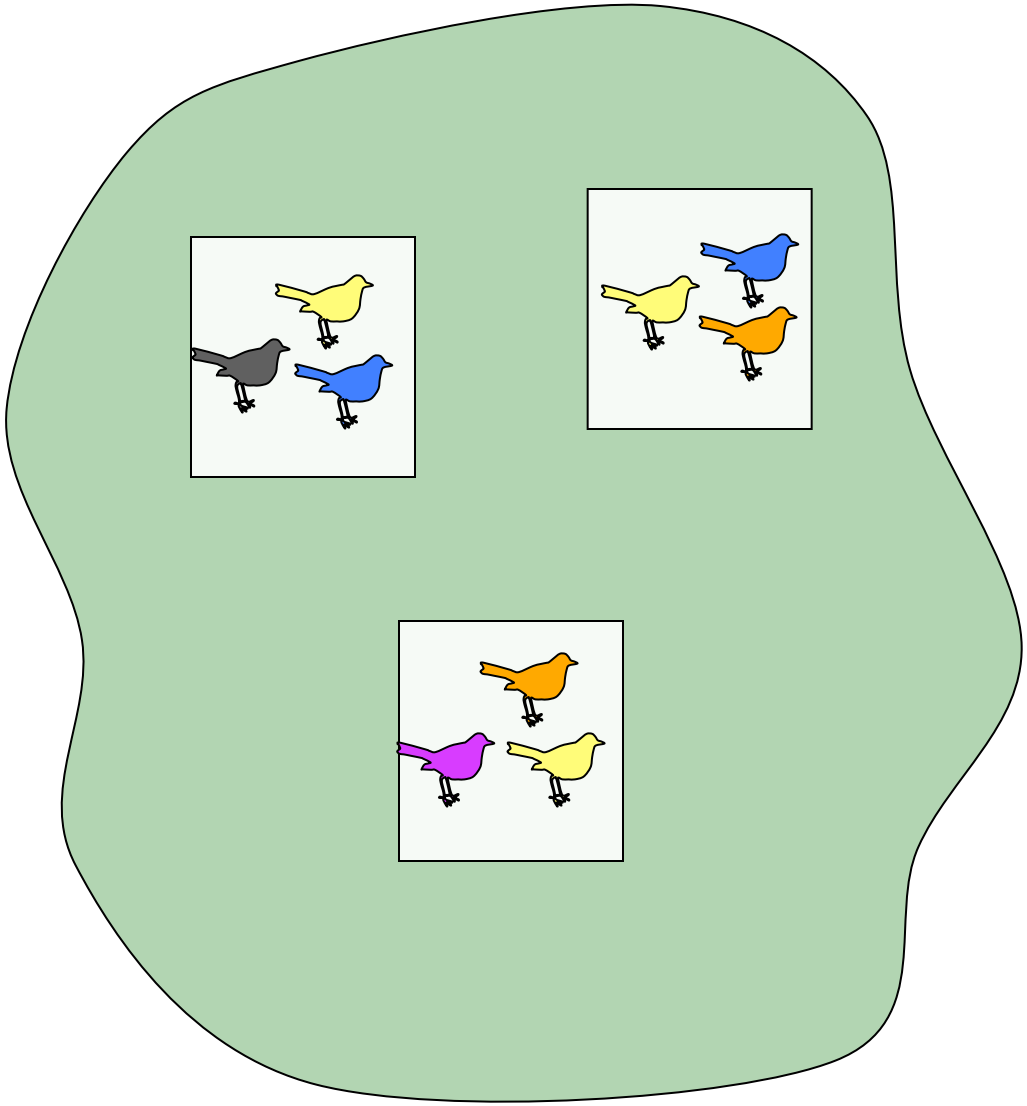
Quantifying spatial components of diversity

Regional pool (γ)



If α diversity $\cong$ γ diversity
→ low β diversity

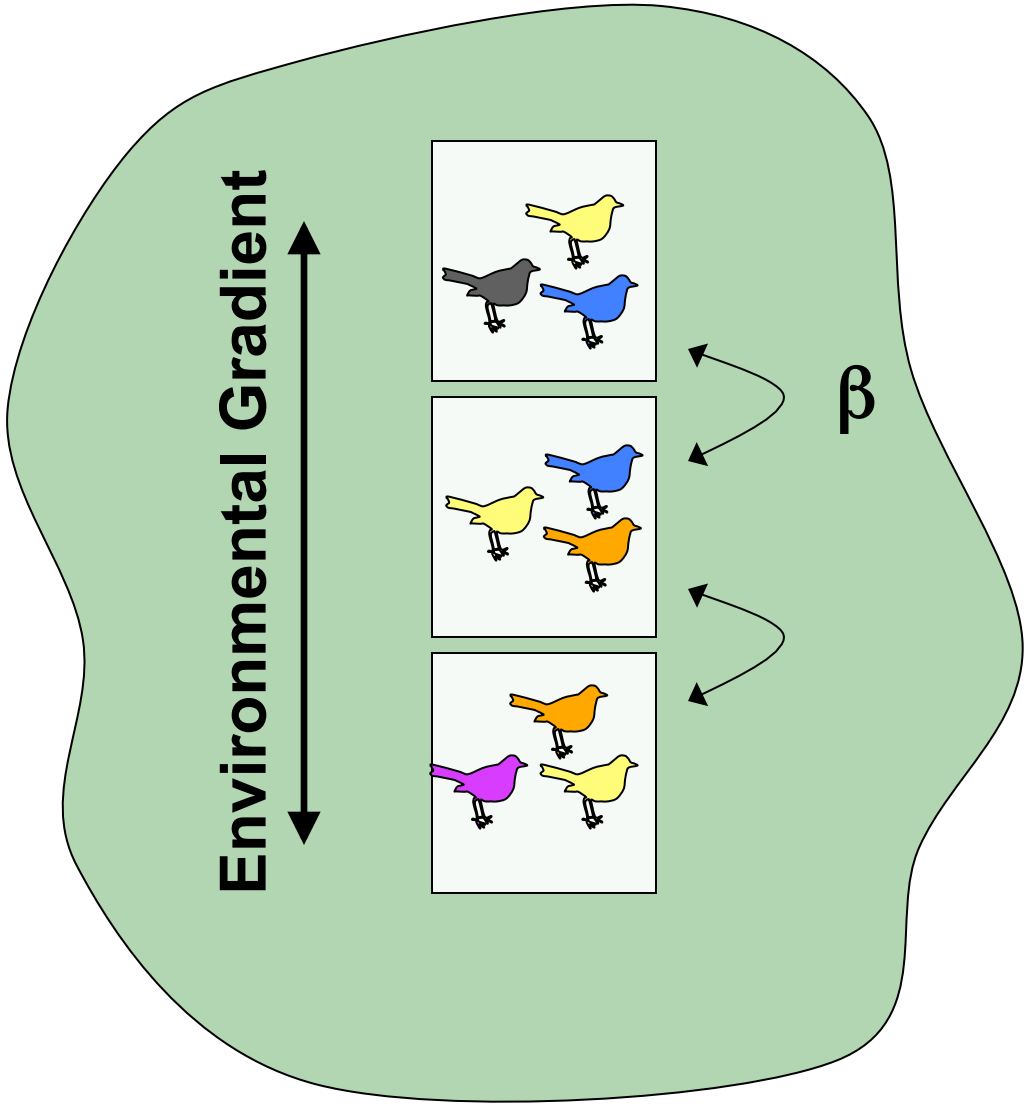
If α diversity < γ diversity
→ high β diversity



Quantifying spatial components of diversity

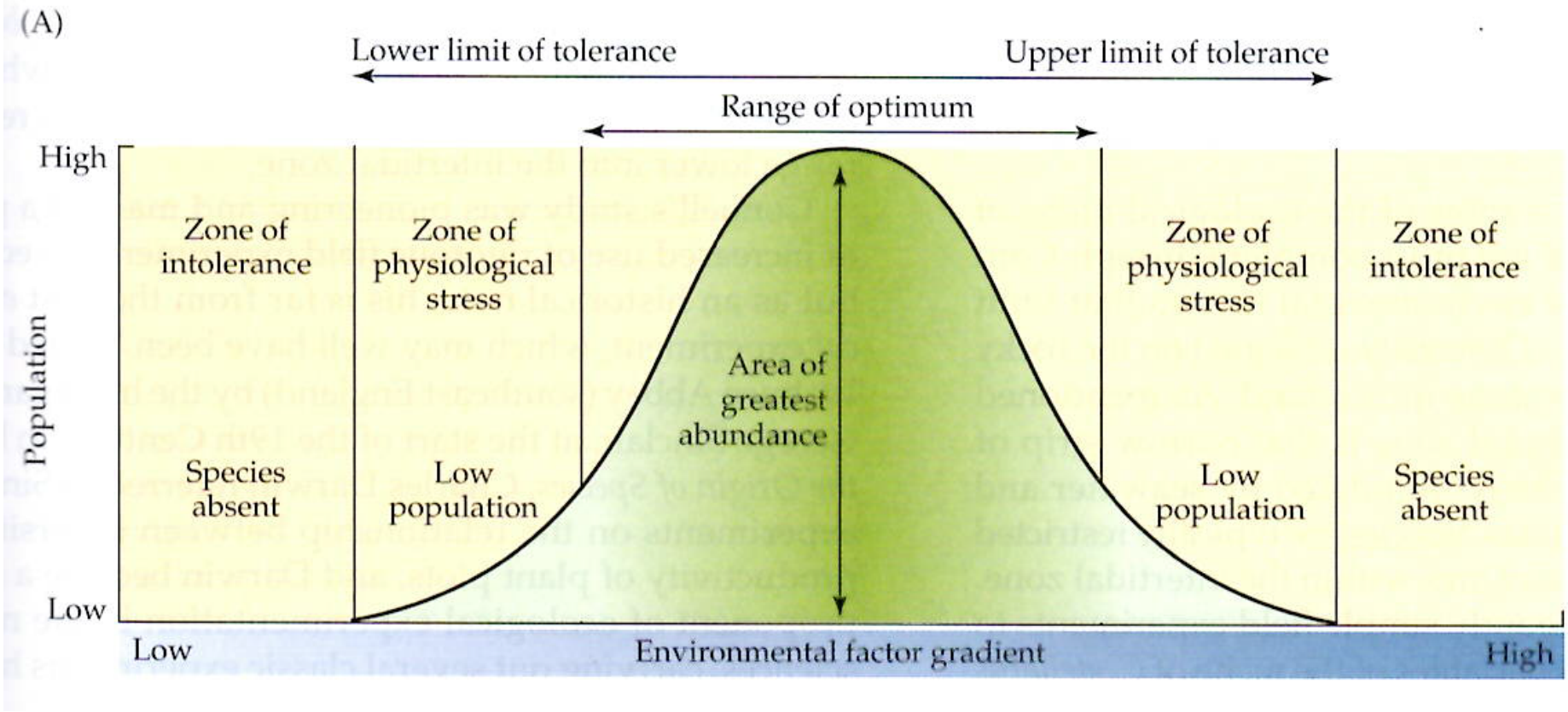
Species turnover:
beta diversity is examined along axis of variation

How does the gradient affect composition?



Recall: Determinants of Distribution

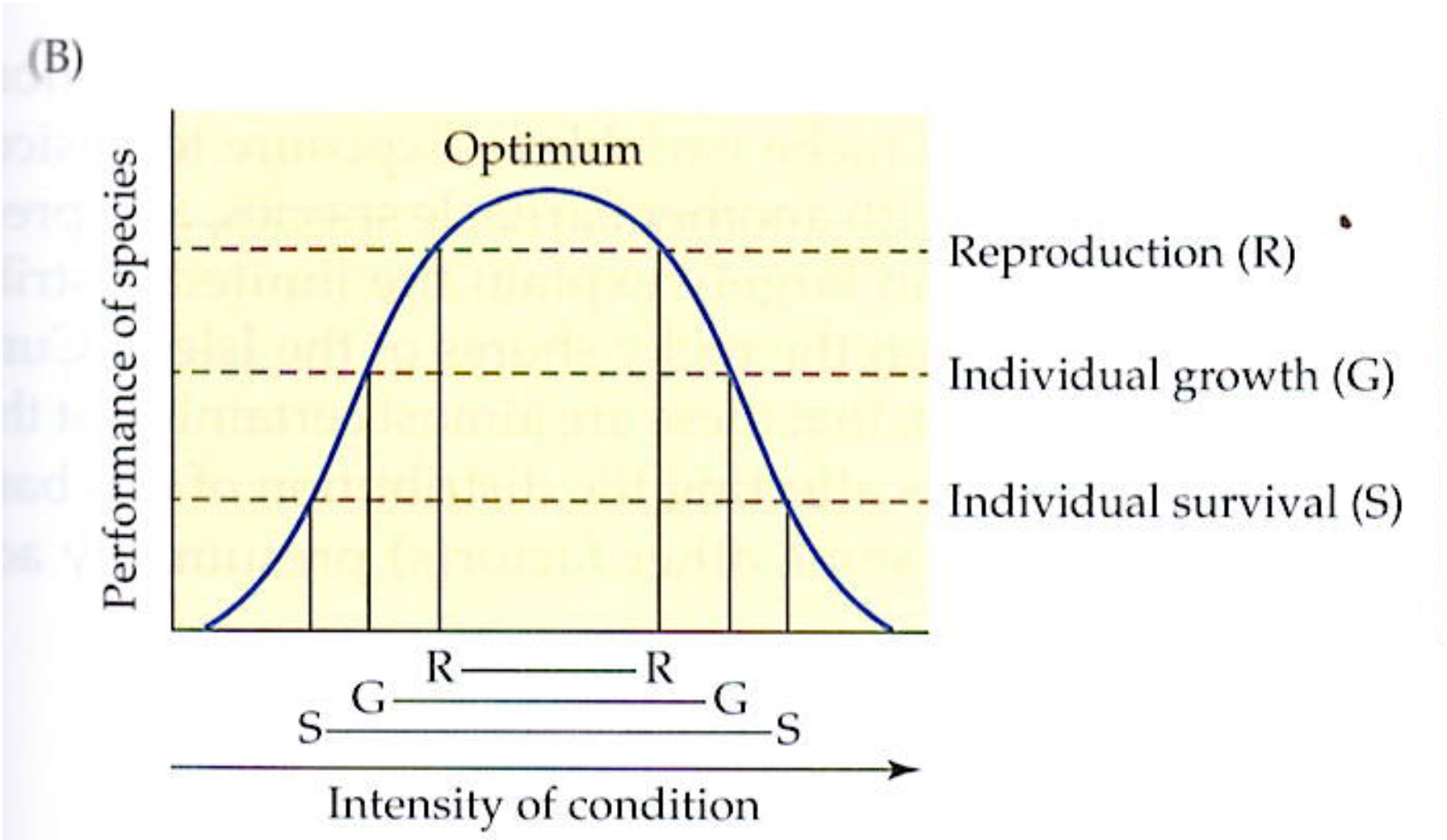
We often expect species to show a Gaussian distribution along a given environmental gradient: the "abundance-center hypothesis"



Multiple environmental factors or gradients can affect a species' distribution – this is what Hutchinson meant by the n-dimensional hypervolume

Determinants of Distribution

The capacity of individuals of a species to survive, grow and reproduce may reach limits at different distances from the optimal condition.



Interdependence of species in communities

One of the longest standing themes in community ecology is the definition of an ecological community

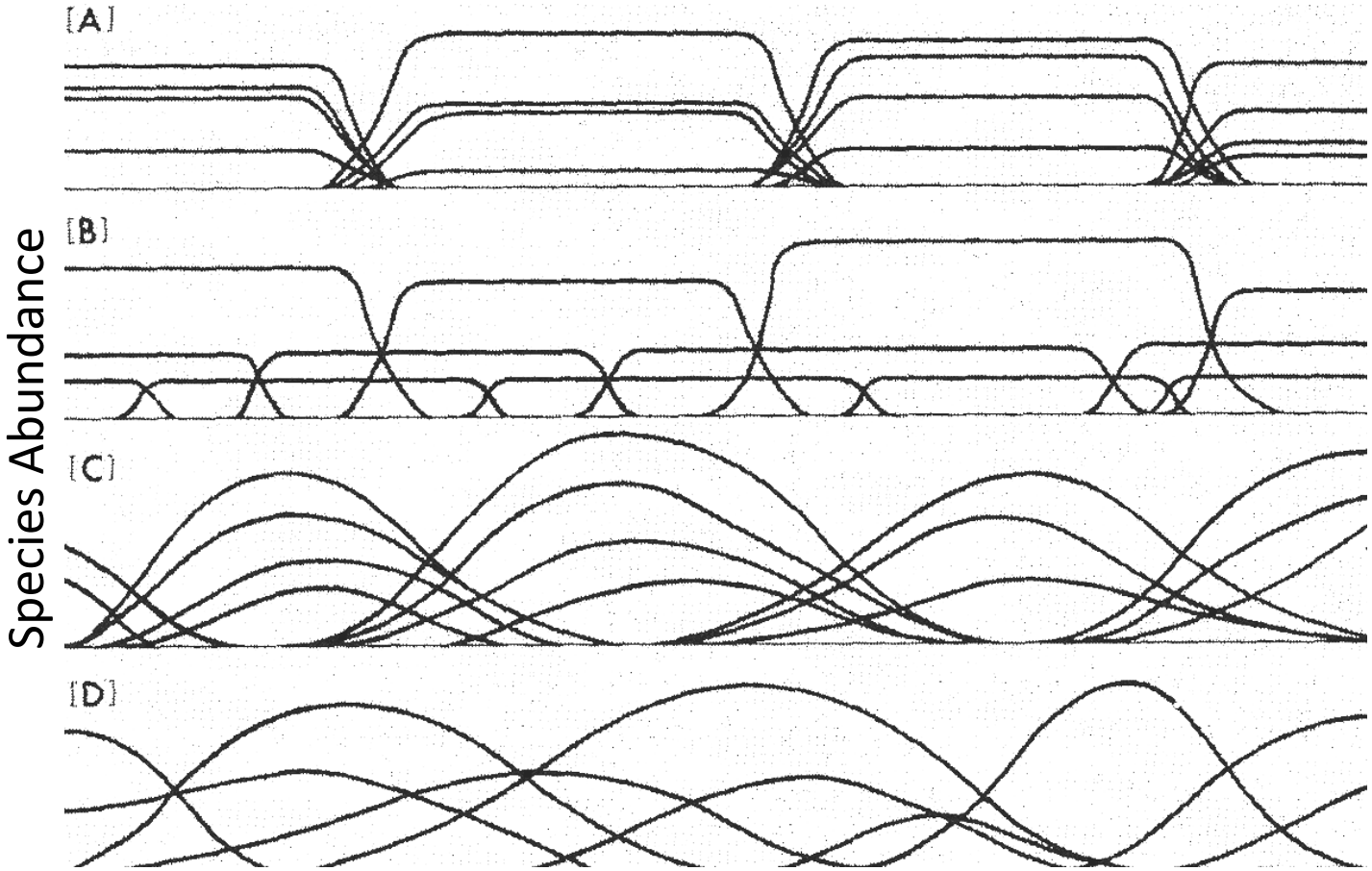
How do we define communities of coexisting species?
What "boundaries" separate one community from another?
To what extent are coexisting species interdependent?

The classic views: cohesive-unit and individualistic communities

The expanding view: communities should not be defined (Ricklefs)

Interdependence of species in communities

Whittaker describes a classic and comprehensive view of the delineation of communities and distribution of species within those communities



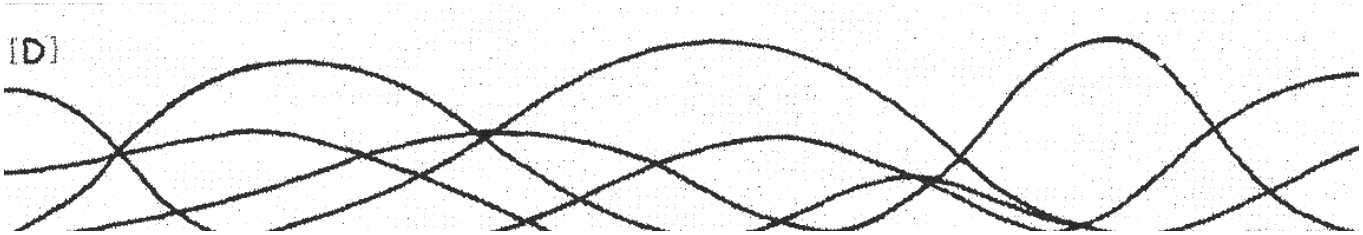
(From Whittaker 1975)

Interdependence of species in communities

Whittaker describes a classic and comprehensive view of the delineation of communities and distribution of species within those communities

Species Abundance

The "individualistic" hypothesis, proposed by Gleason, states that species do not occur in definable communities

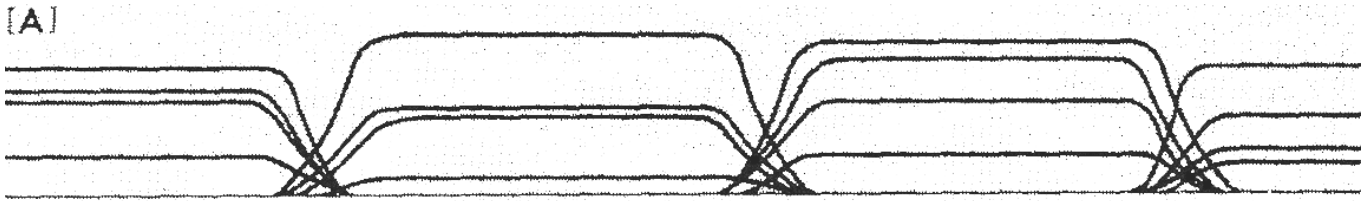


Environmental gradient

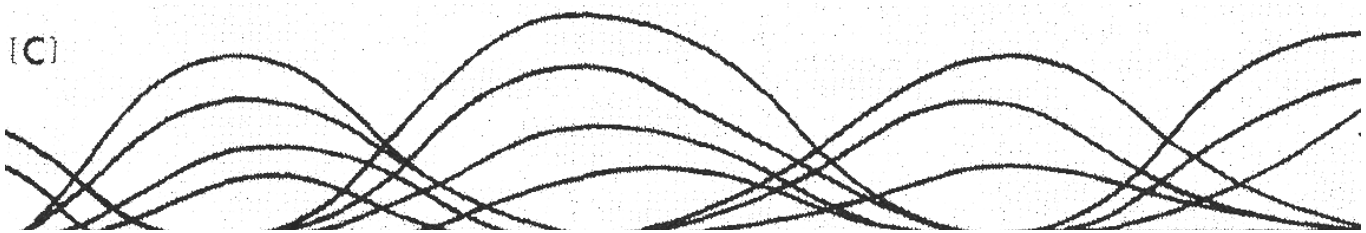
(From Whittaker 1975)

Interdependence of species in communities

Whittaker describes a classic and comprehensive view of the delineation of communities and distribution of species within those communities



Clements proposed that species co-occur as definable units; species within communities are interdependent and coevolved



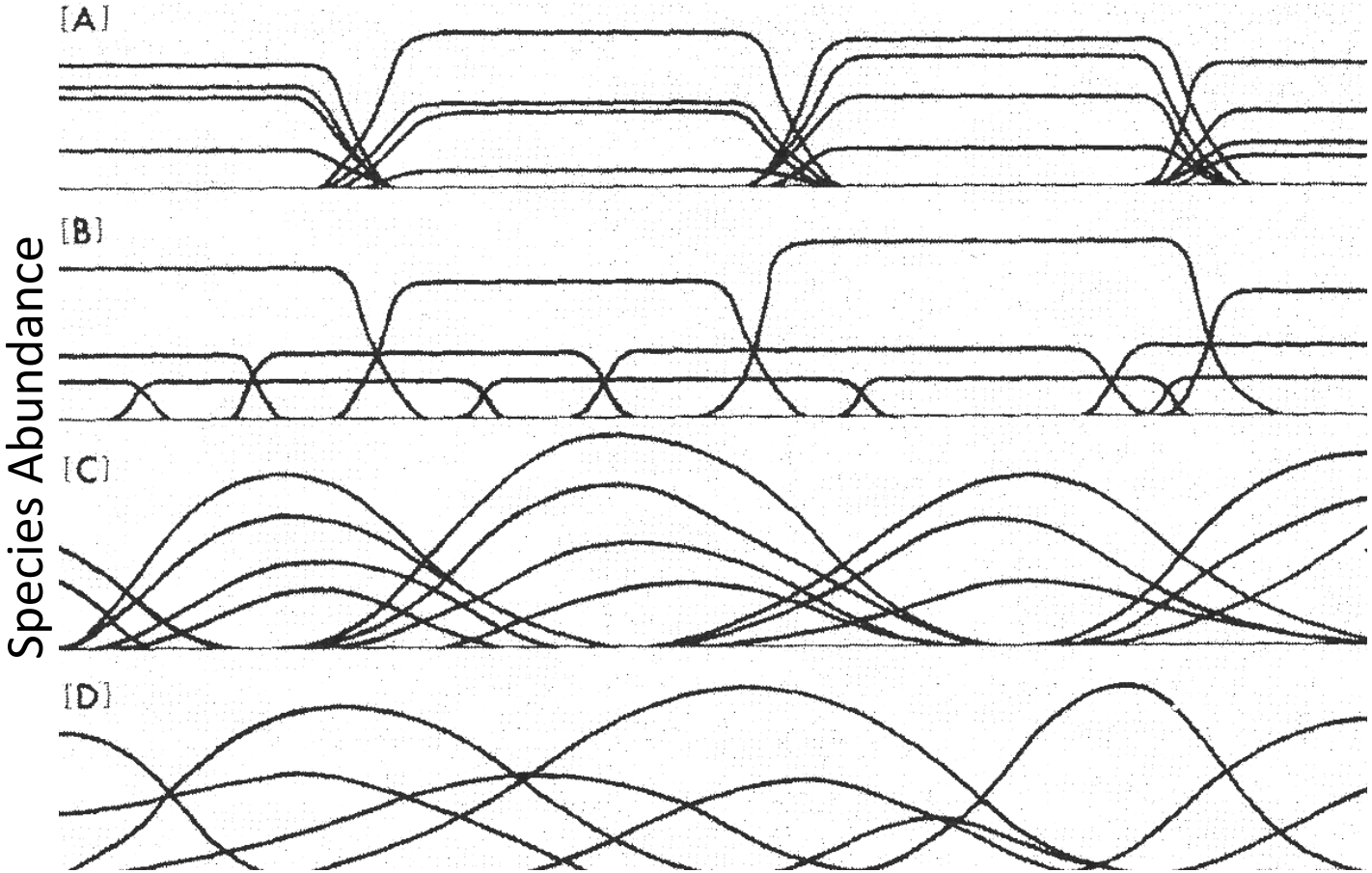
Species Abundance

Environmental gradient

(From Whittaker 1975)

Interdependence of species in communities

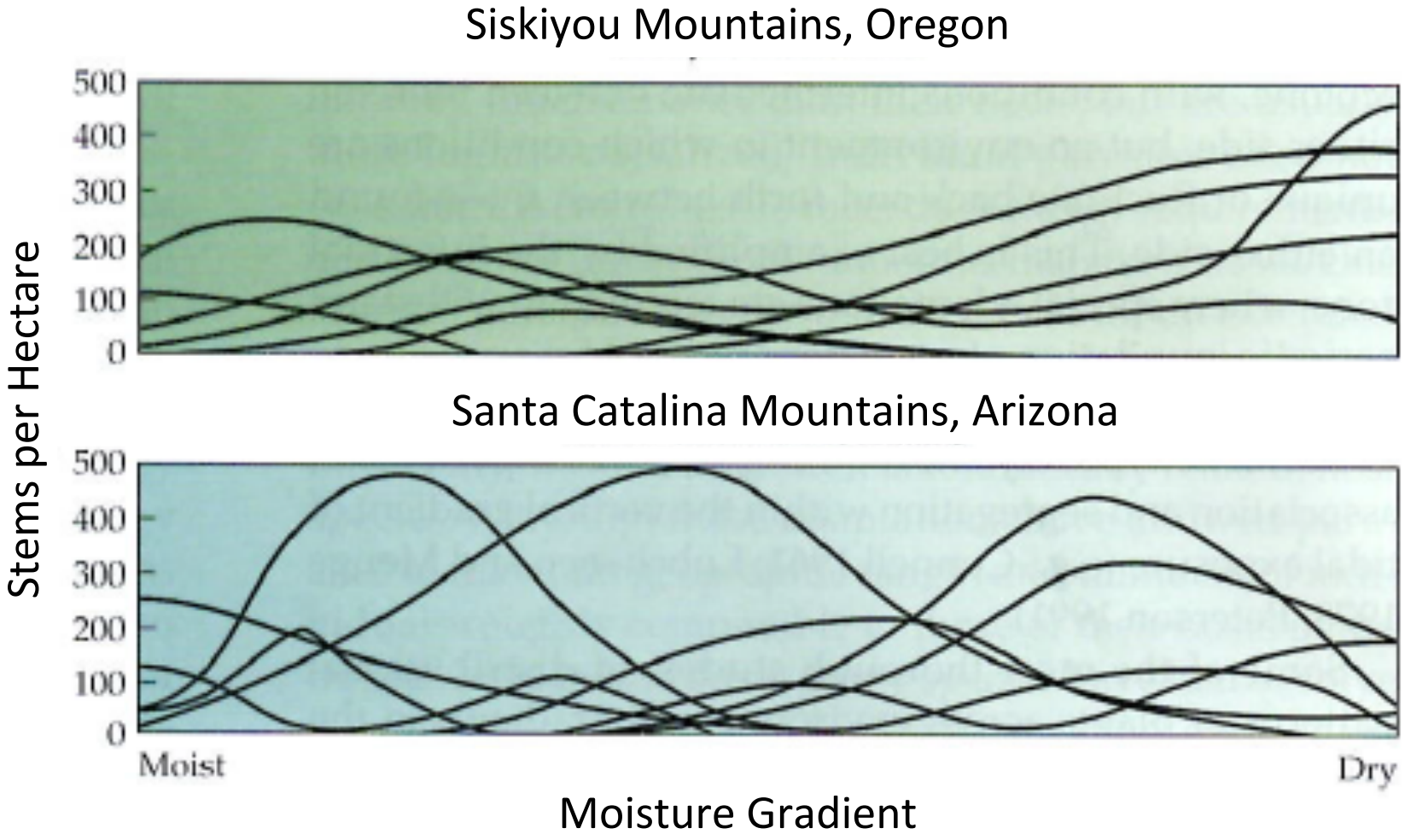
Whittaker combines both individualistic and community-unit scenarios including biotic processes (also competitive interactions and species replacements)



(From Whittaker 1975)

Interdependence of species in communities

Whittaker tested these hypothesized distribution patterns with trees species in two different temperate mountain ranges

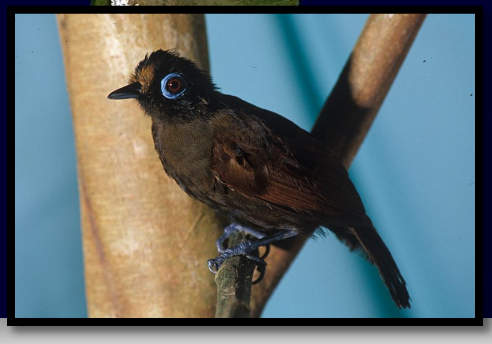


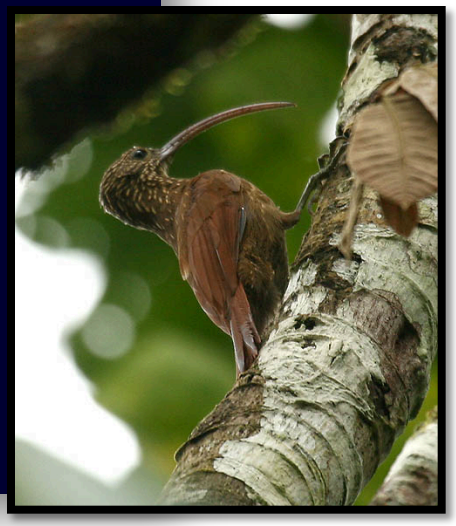
After Whittaker 1967, Lomolino et al. 2017

Community Phylogenetics:
A case study with Neotropical birds

3300 species in South America (1/3 of global)

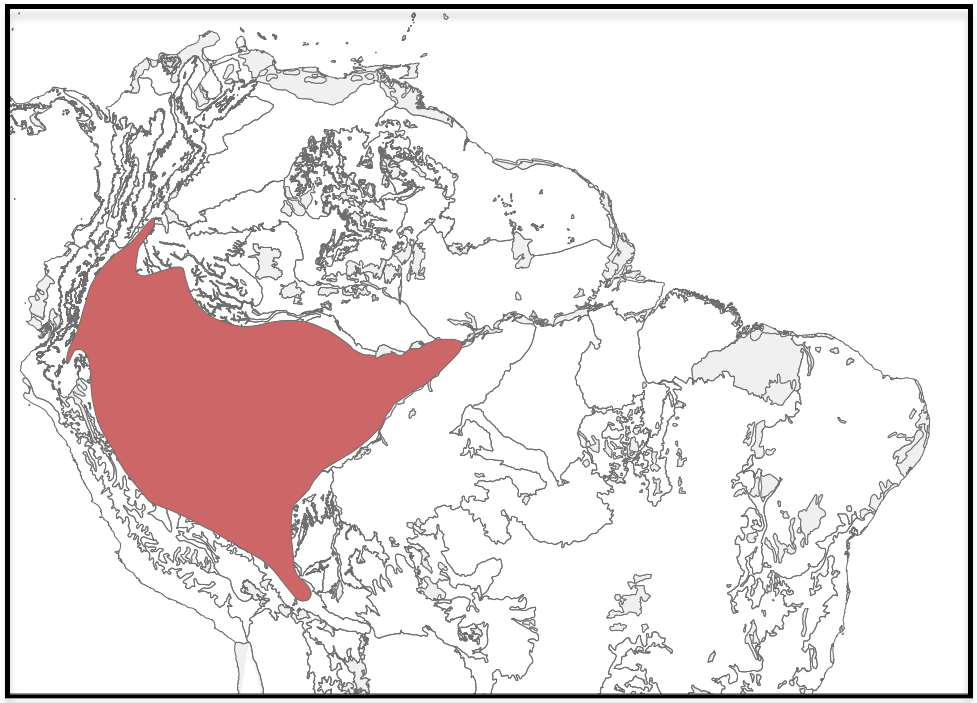
2650 species in tropical Andes and Amazonian lowlands





Expansive ranges of Amazonian birds

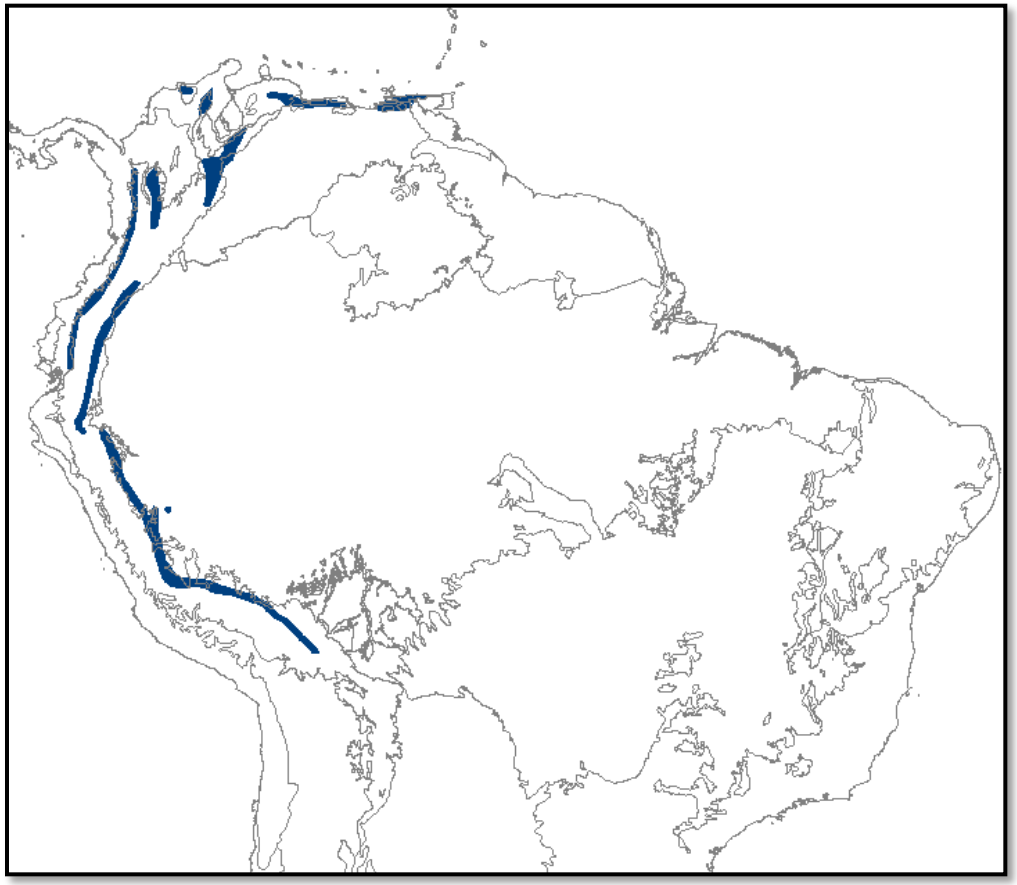
Hairy-crested Antbird
Rhegmatorhina melanosticta



Ridgely et al. 2005; Digital Distribution Maps of Birds of Western Hemisphere

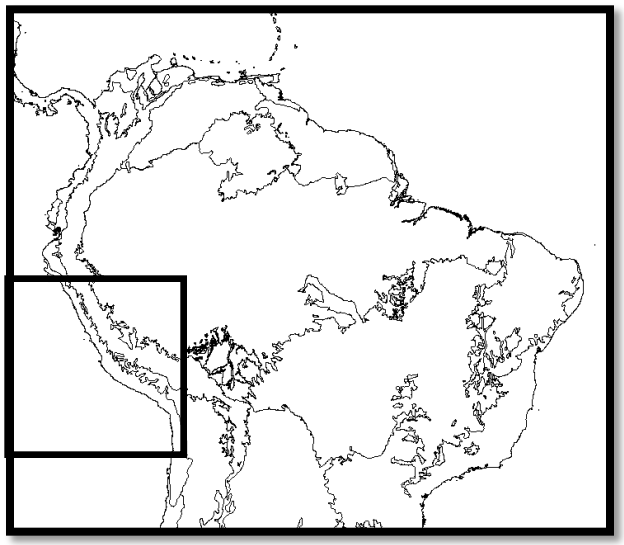
“Shoestring” distributions of montane birds

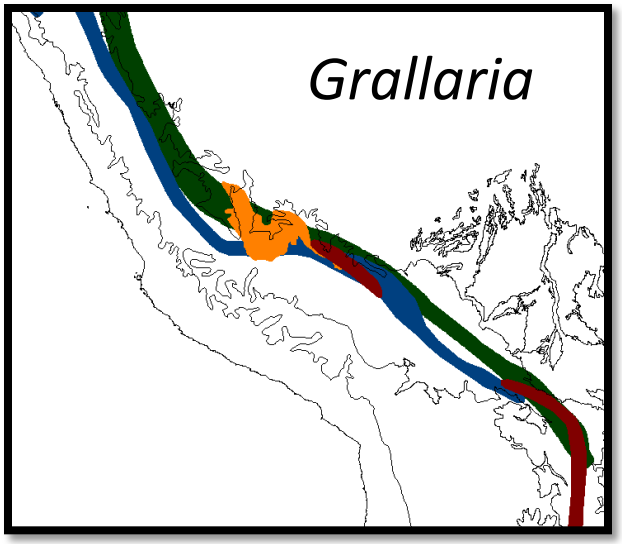
Long-tailed Antbird
Drymophila caudata

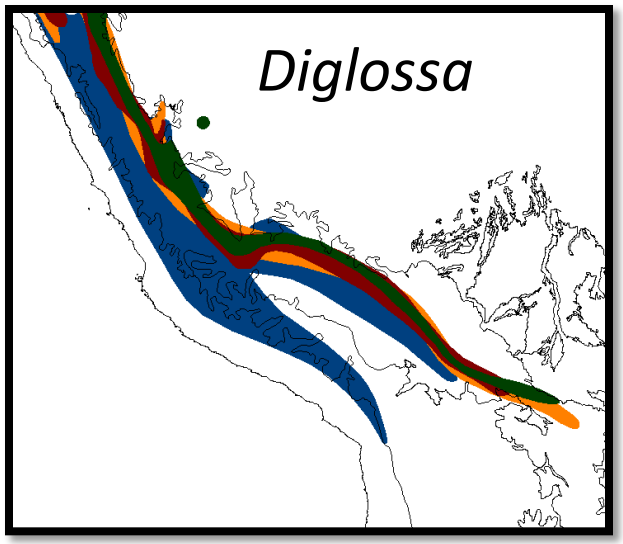


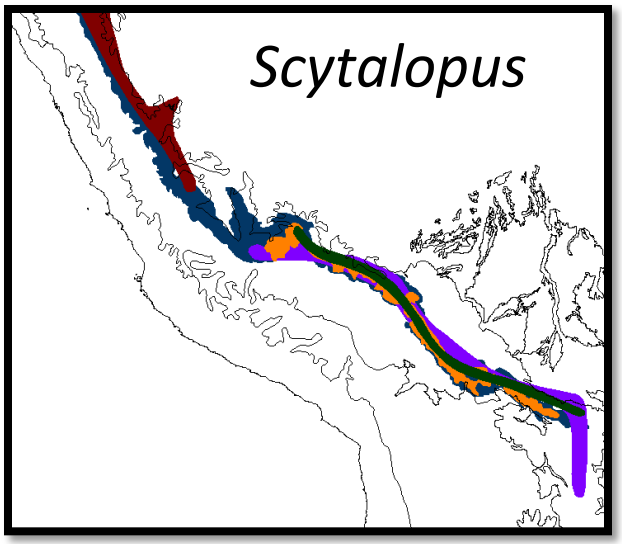
NatureServe InfoNatura Database

Narrow ranges of montane species generate high species turnover (aka high beta diversity)









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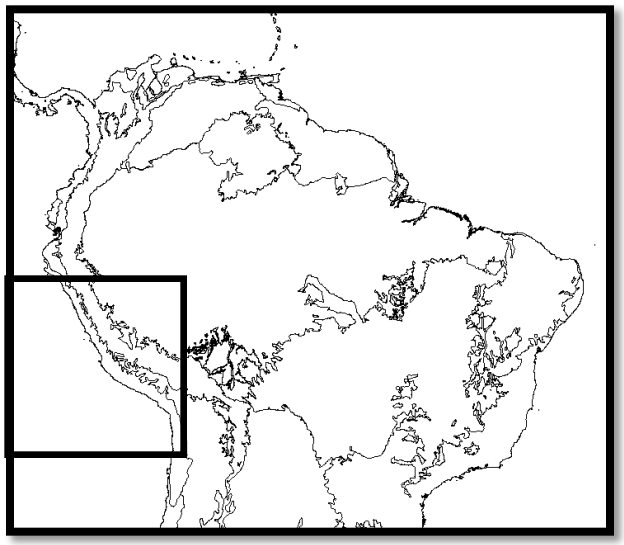
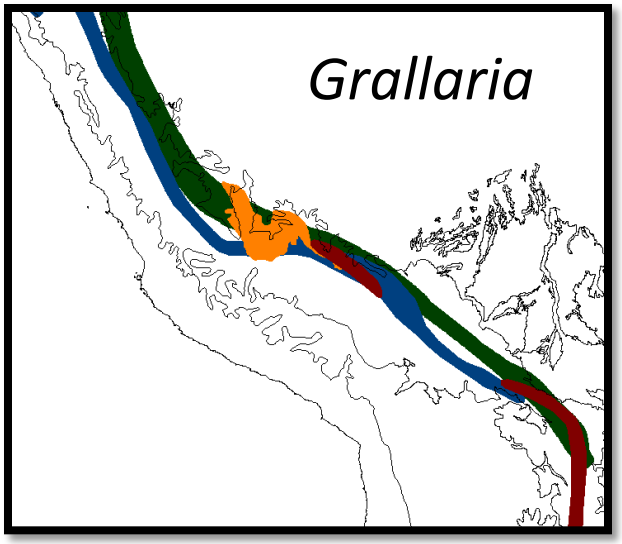
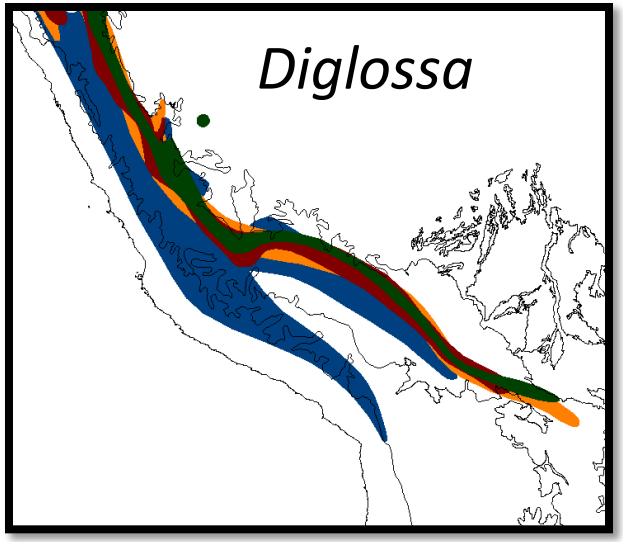
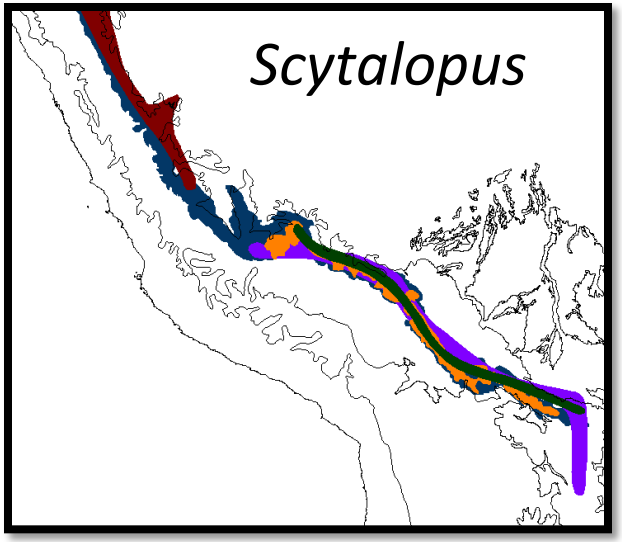
Distinct communities are found at different elevations
How are these communities structured?







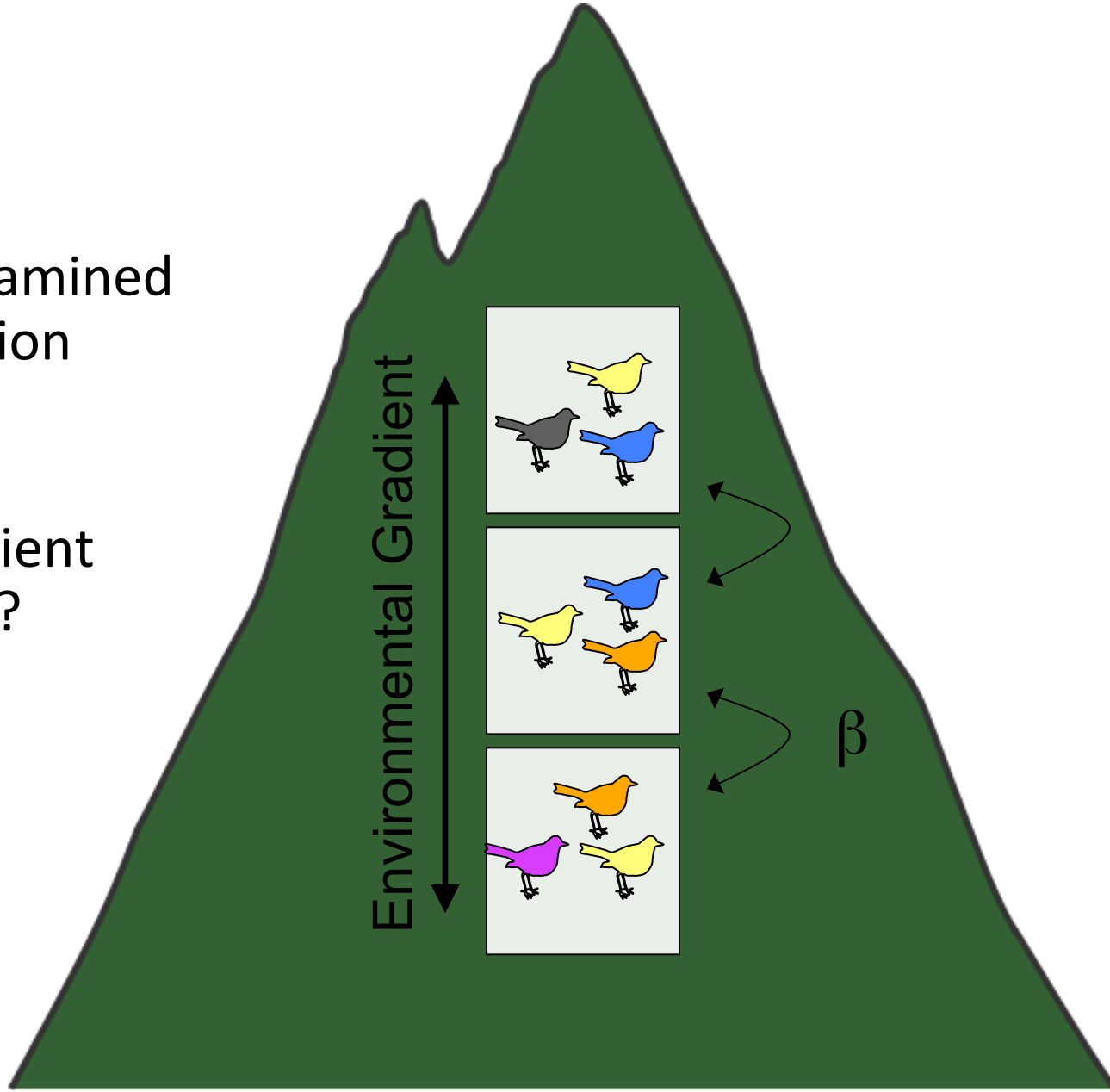


NatureServe InfoNatura Database

Quantifying spatial components of diversity

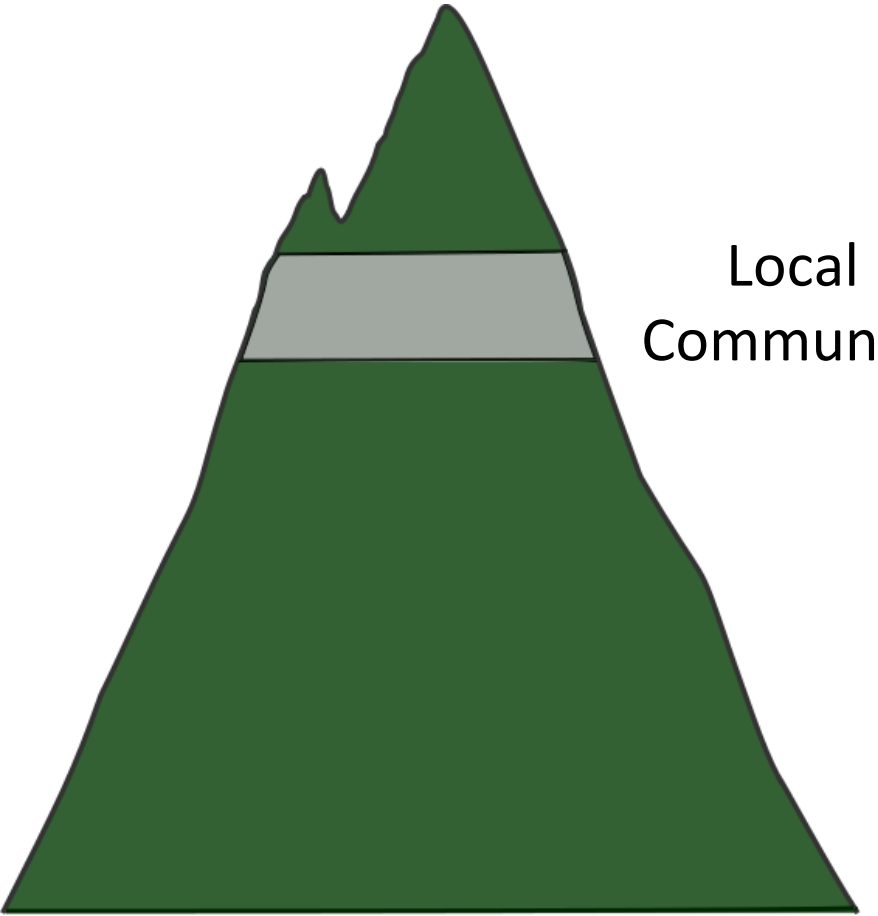
Species turnover:
beta diversity is examined along axis of variation

How does the gradient affect composition?



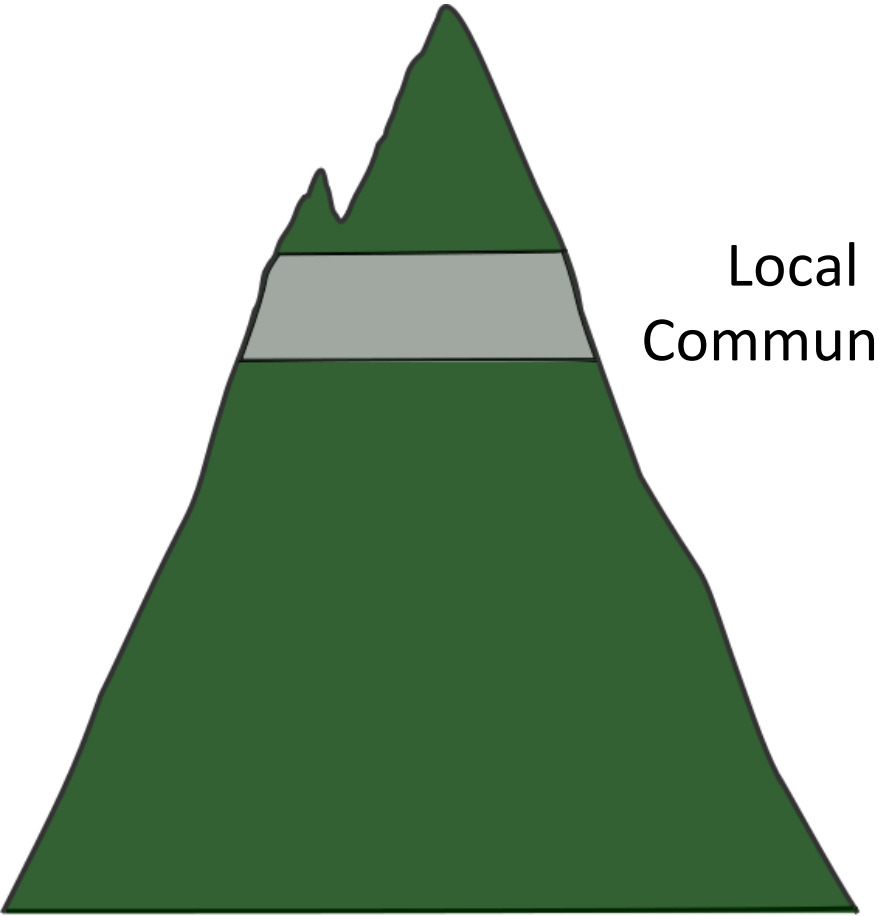
What can a evolutionary perspective tell us?

Ecological and evolutionary processes regulate community assembly



What can a evolutionary perspective tell us?

Ecological and evolutionary processes regulate community assembly



Local Community

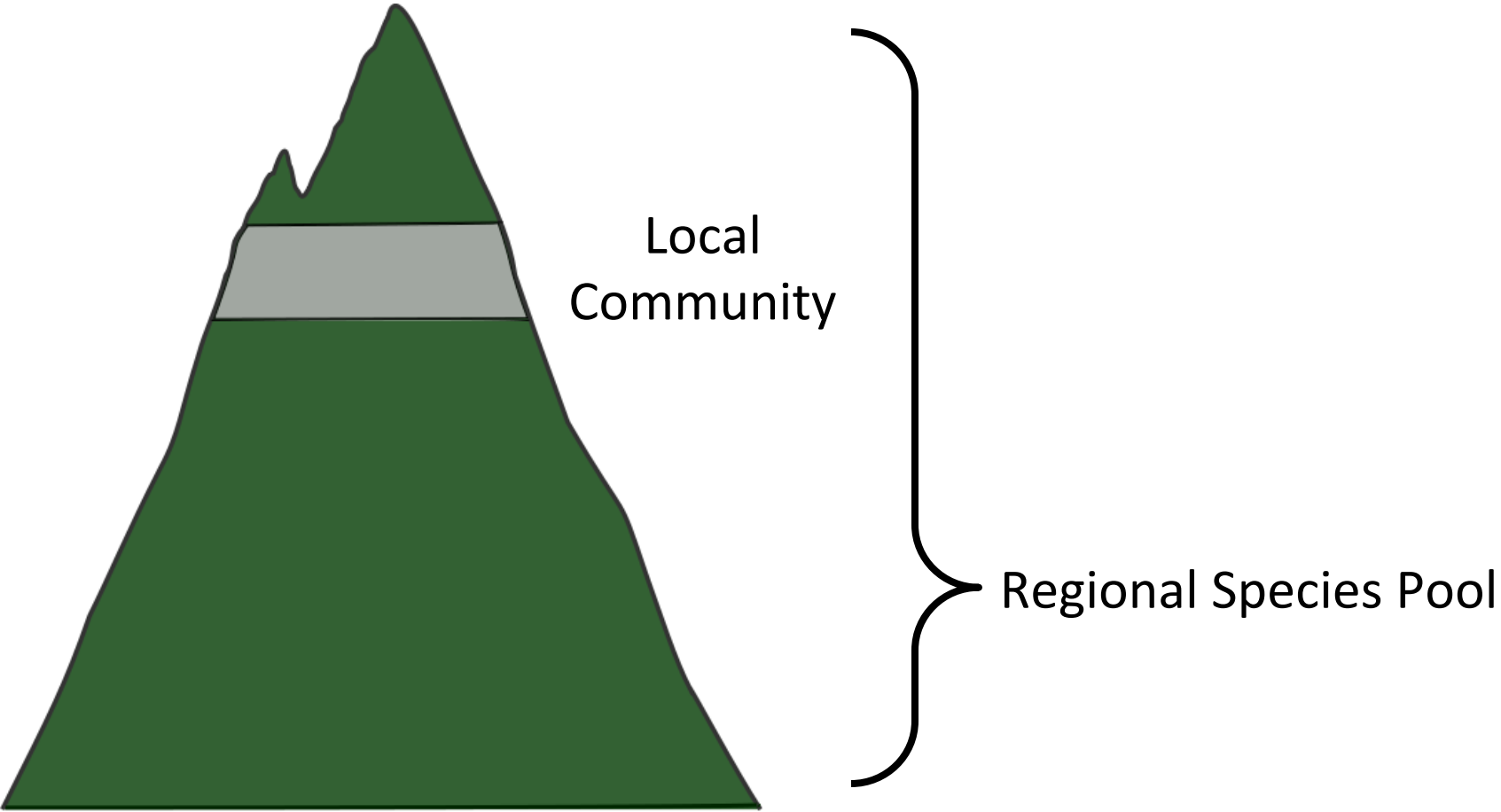
The local community is an area sampled within a larger region

Species in a local area should undergo some process of ecological sorting due to numerous types of interactions

Looking at relationships of coexisting species can point us towards processes responsible for ecological sorting…

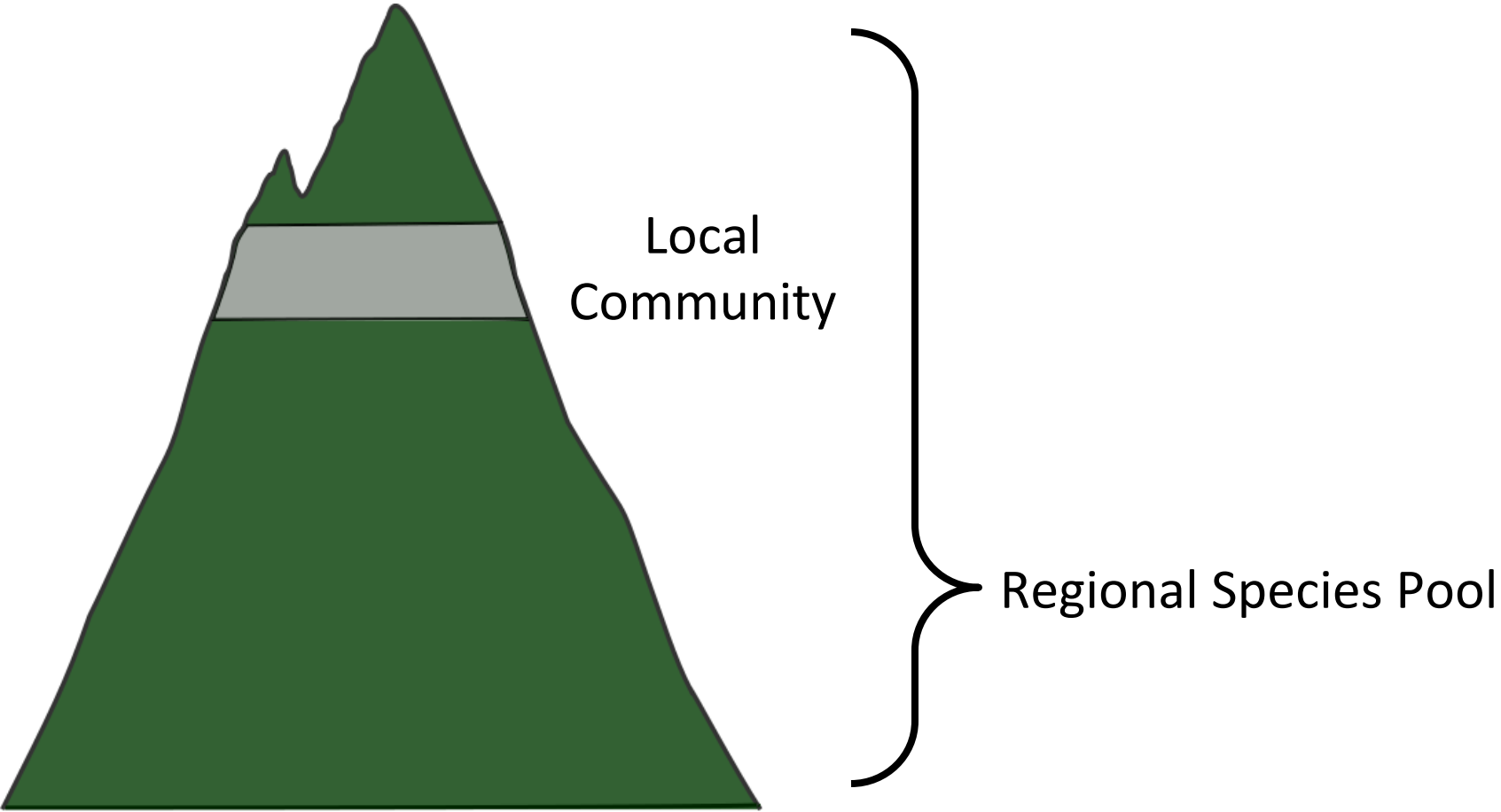
What can a phylogenetic perspective tell us?

Ecological sorting in communities due to habitat filters and species interactions



What can a phylogenetic perspective tell us?

Environmental gradients and biogeographic history of lineages influence dispersal, speciation and extinction



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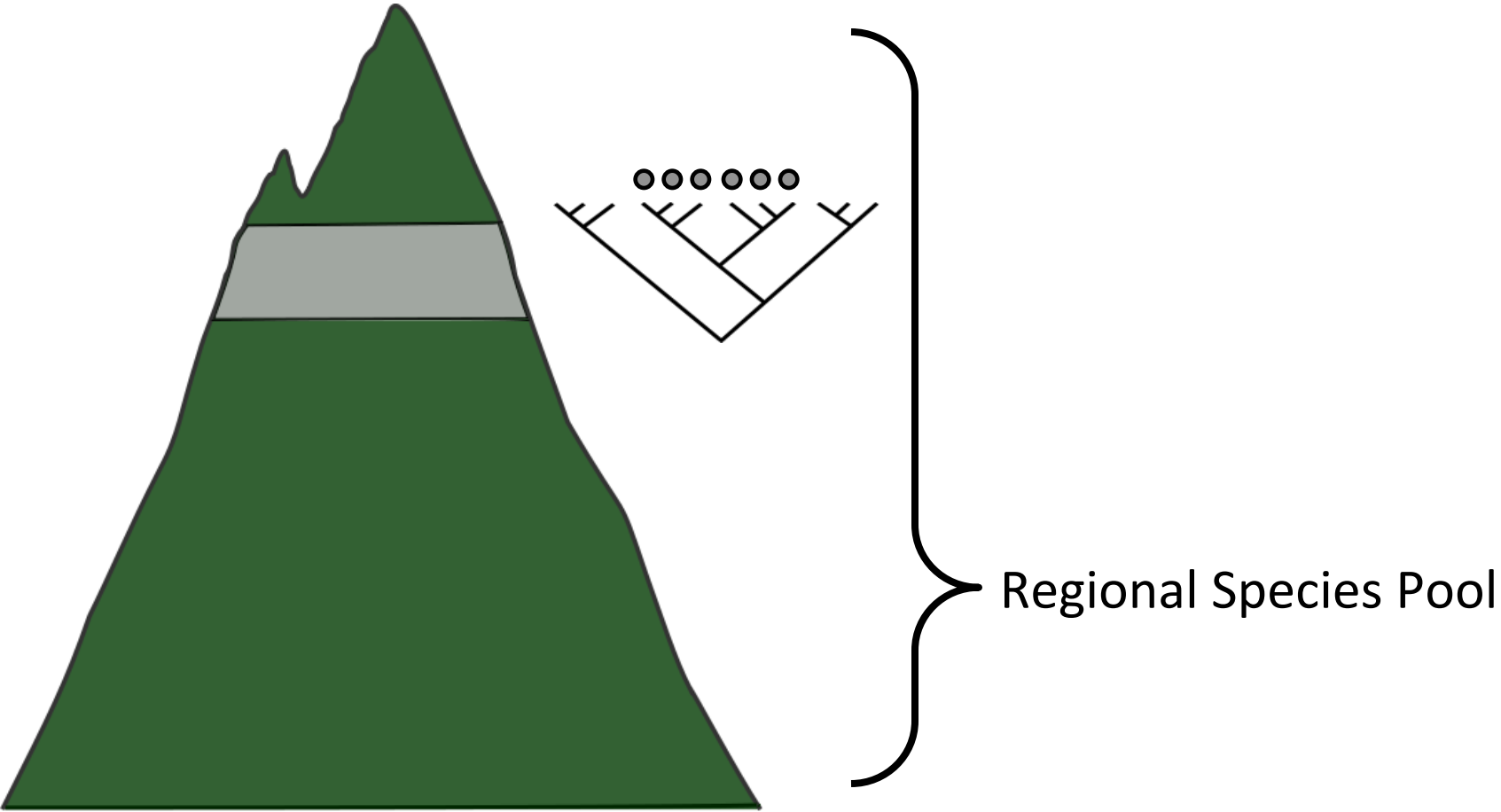
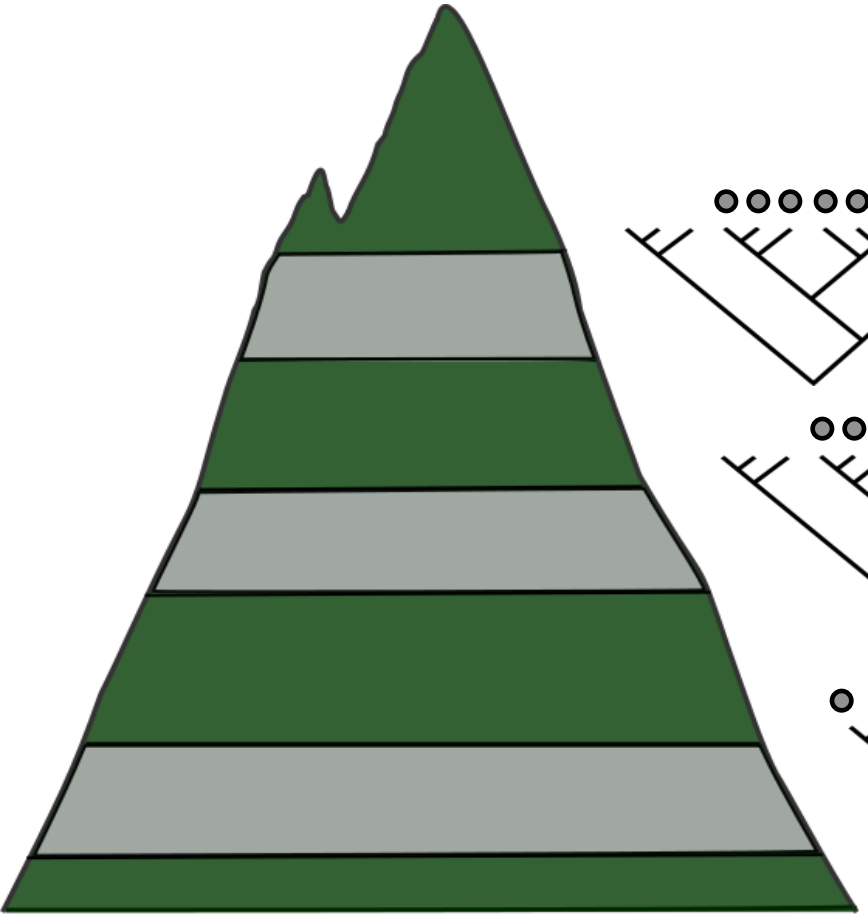
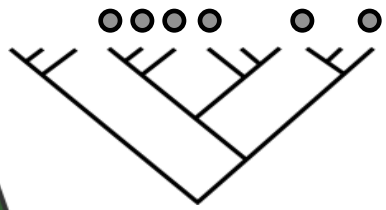


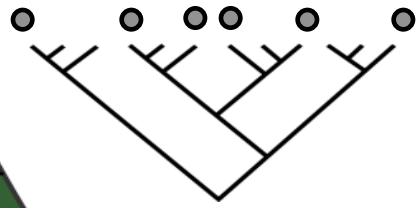
What can a phylogenetic perspective tell us?

How does the phylogenetic structure of communities change with elevation?



Phylogenetic Clustering
Co-occurring species are
more closely related

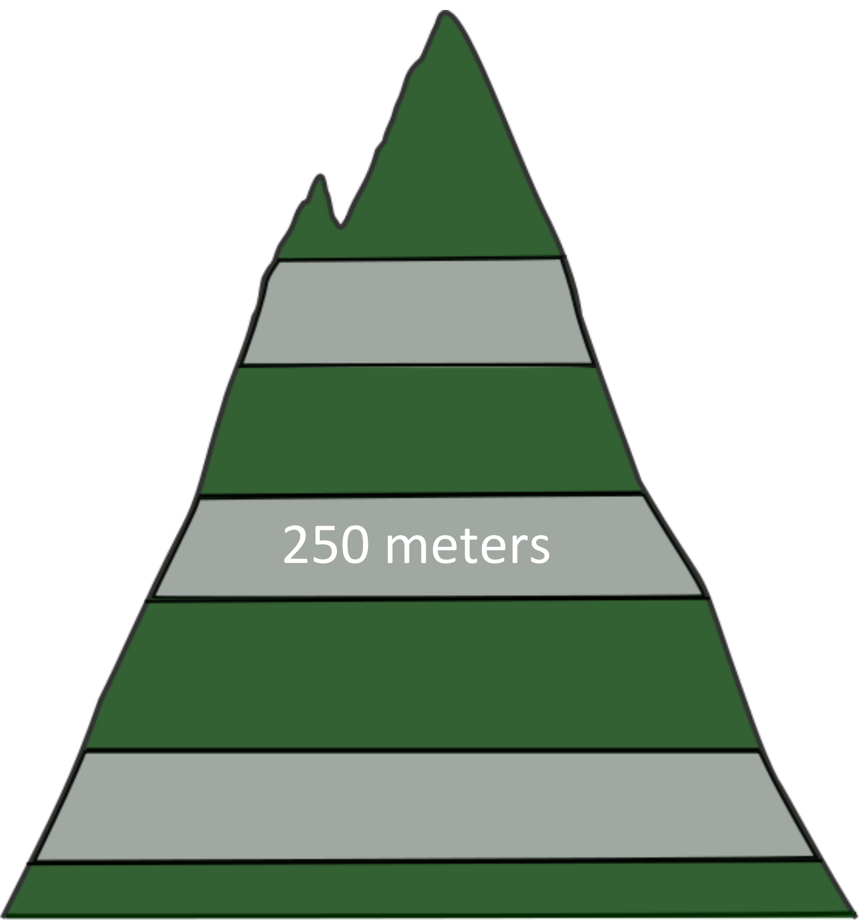




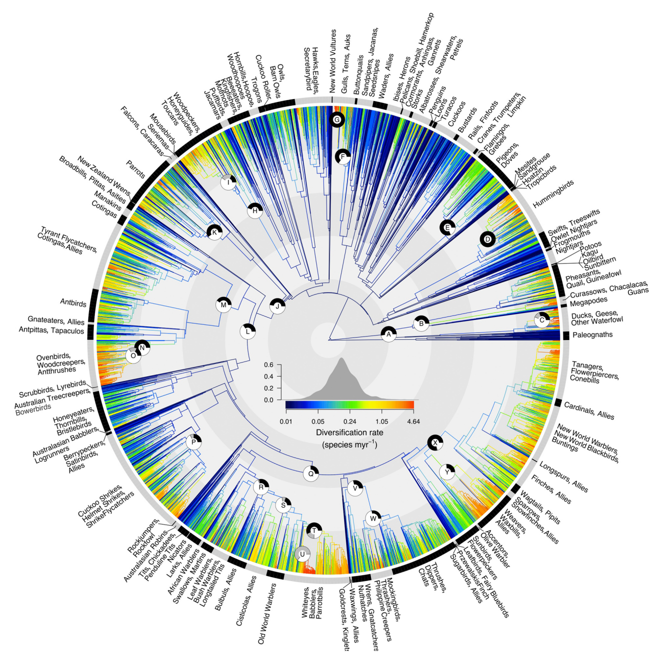
Phylogenetic Overdispersion
Co-occurring species are
more distantly related

A phylogenetic view of Andean bird communities

Used lists of species occurring in each 250-m elevational band



Combined with a distribution of
2,000 trees drawn at random
(from Jetz et al., 2012)



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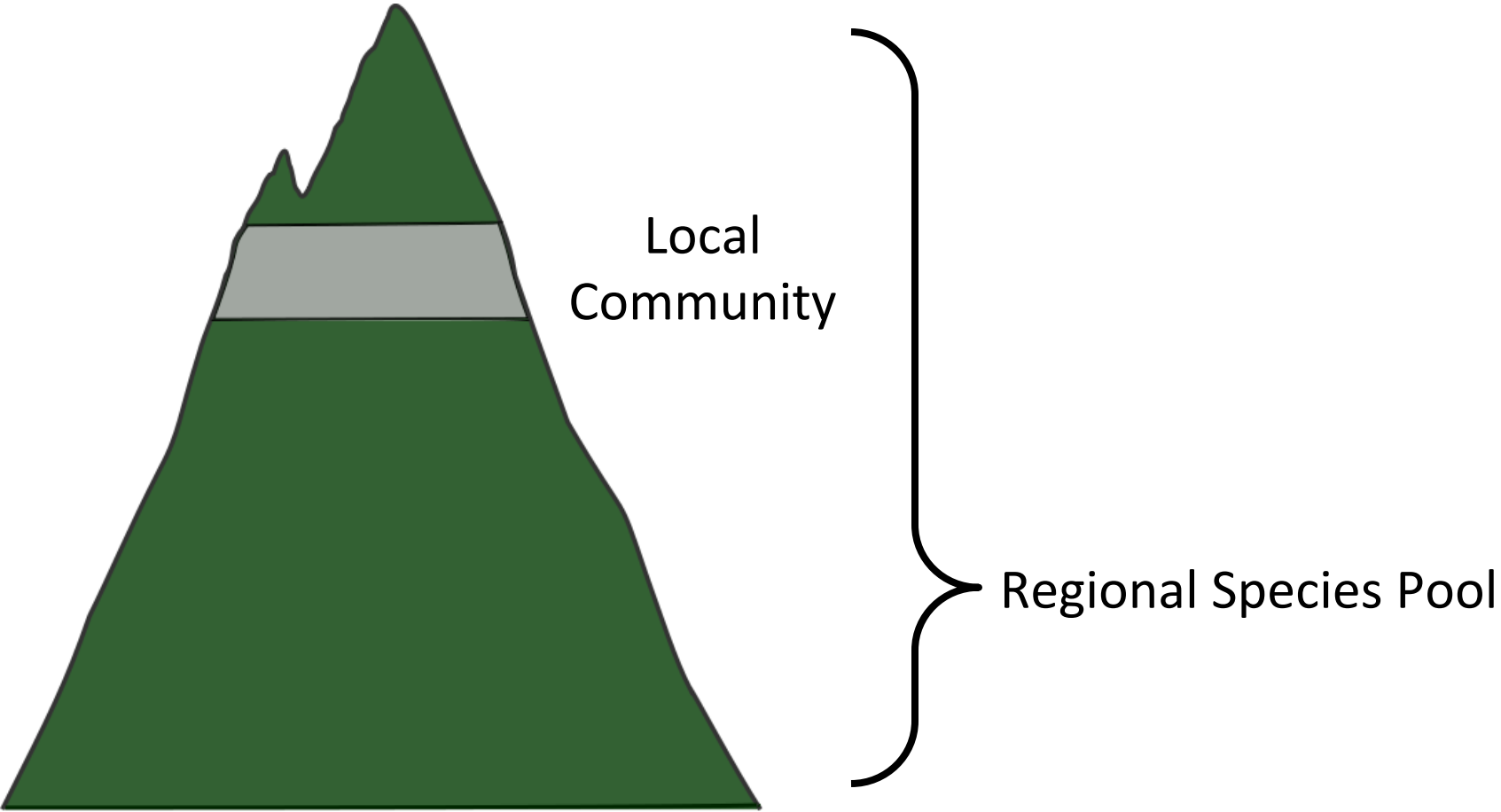
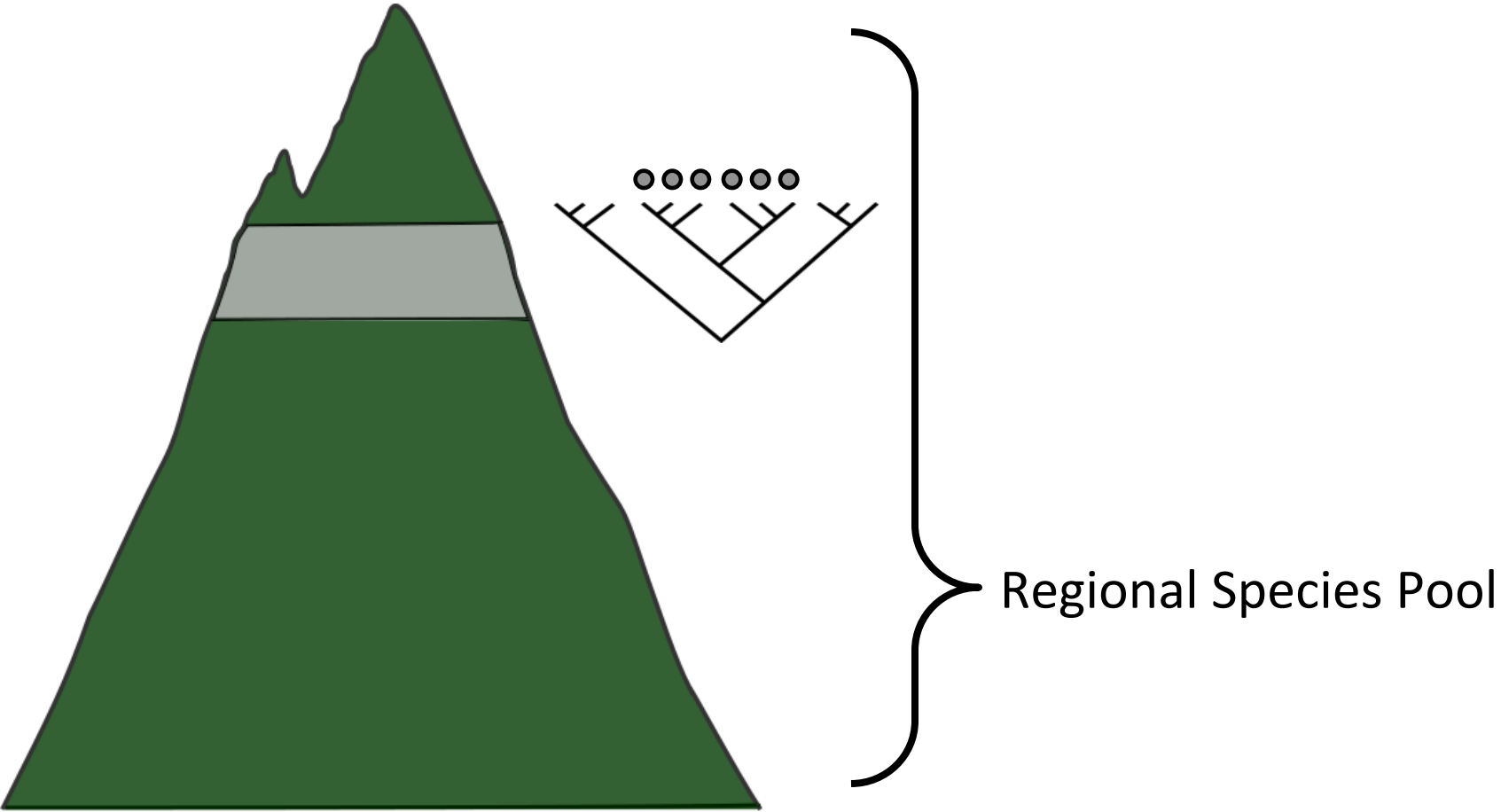


What can a evolutionary perspective tell us?

We can look at the phylogenetic relationships among species occurring in the local community



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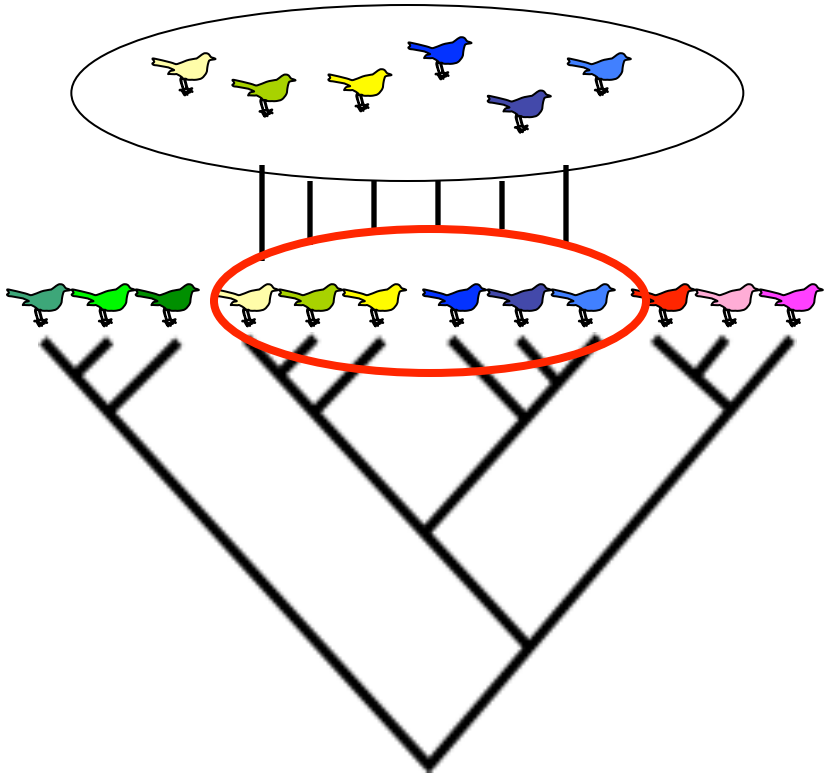

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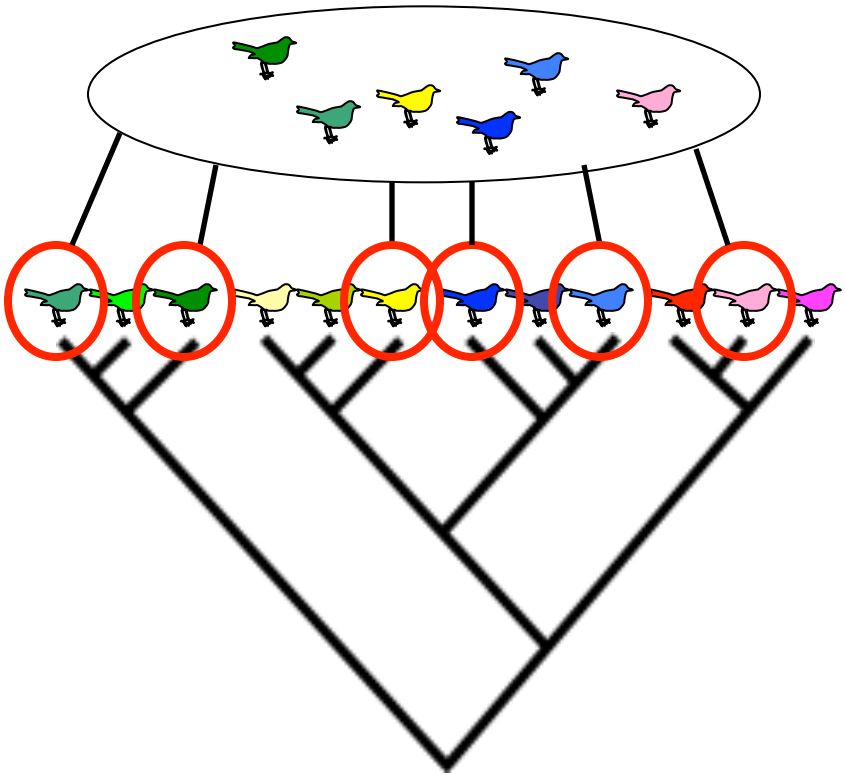

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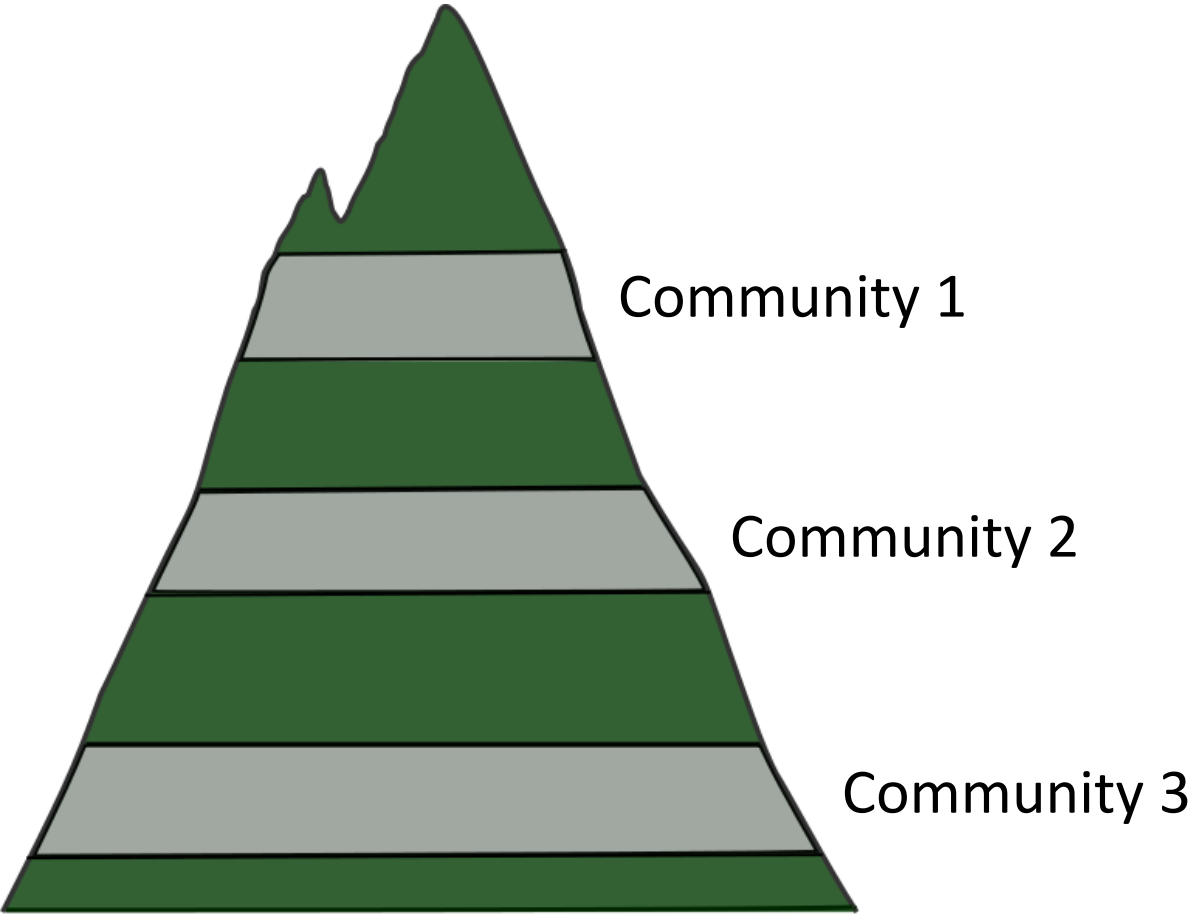

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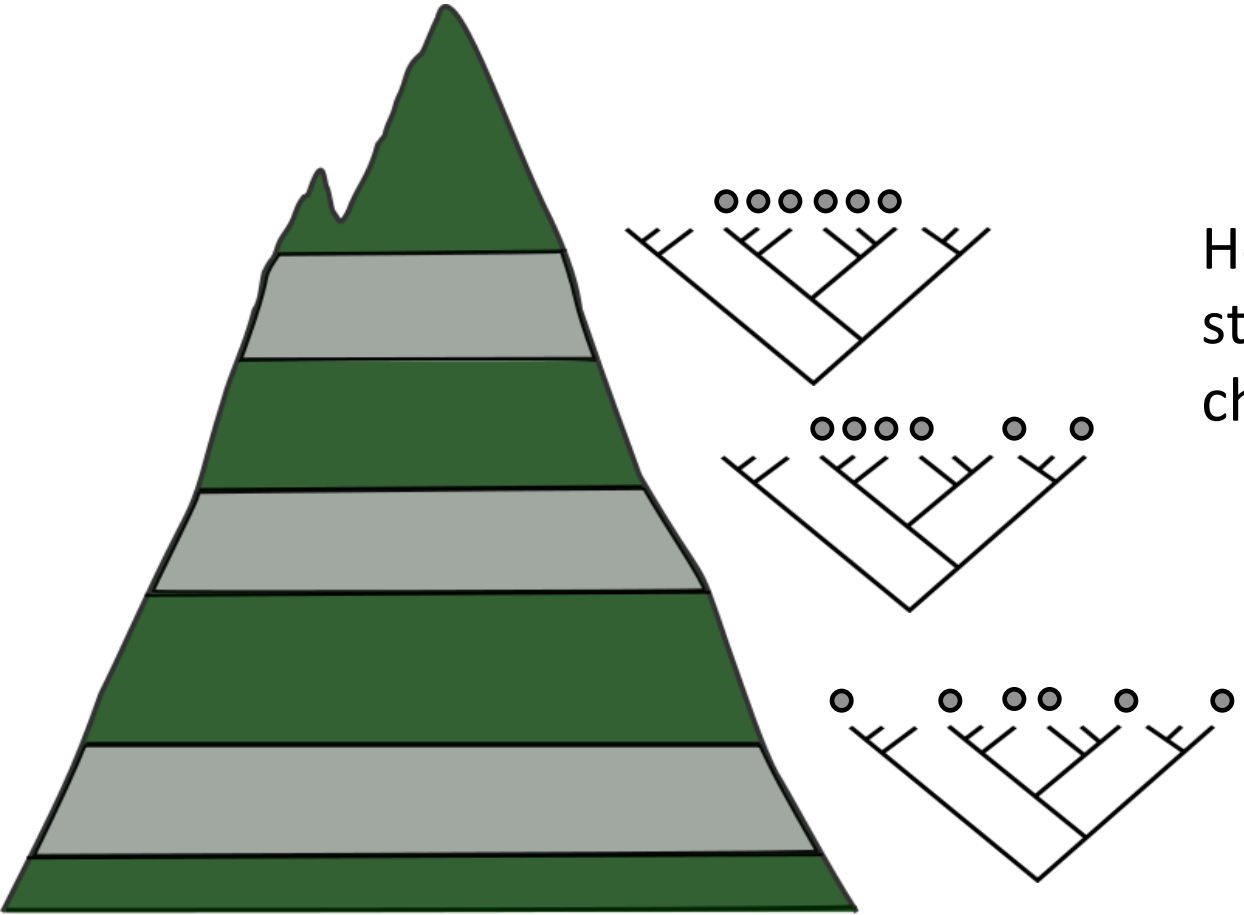
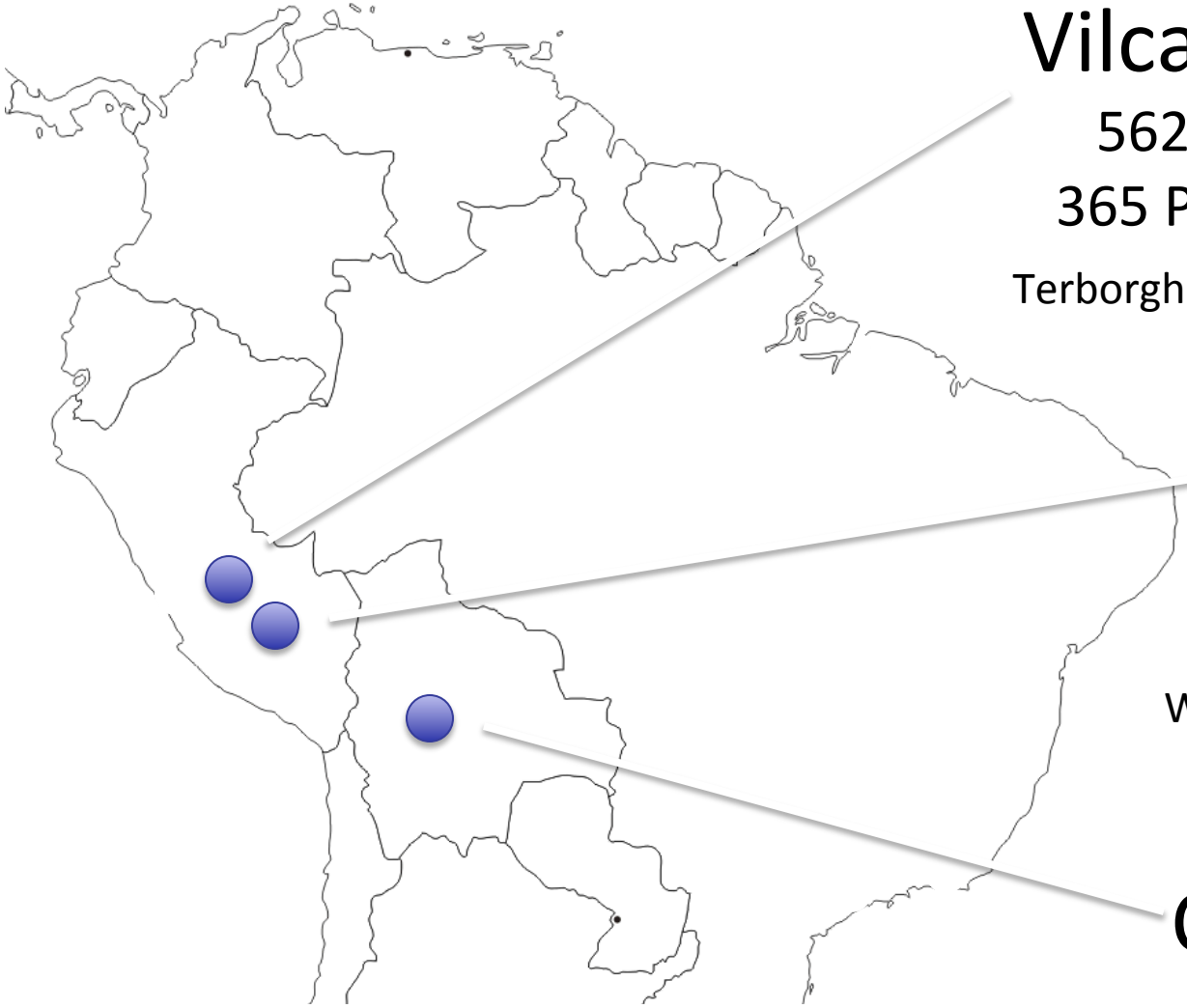


How does phylogenetic structure of communities change with elevation?

300-3600 meters



Vilcabamba

562 species

365 Passerines

Terborgh 1971, *Ecology*

Manu

913 species

537 Passerines

Walker et al. 2006, *Fieldiana*

Carrasco

419 species

269 Passerines

unpublished

300-3600 meters

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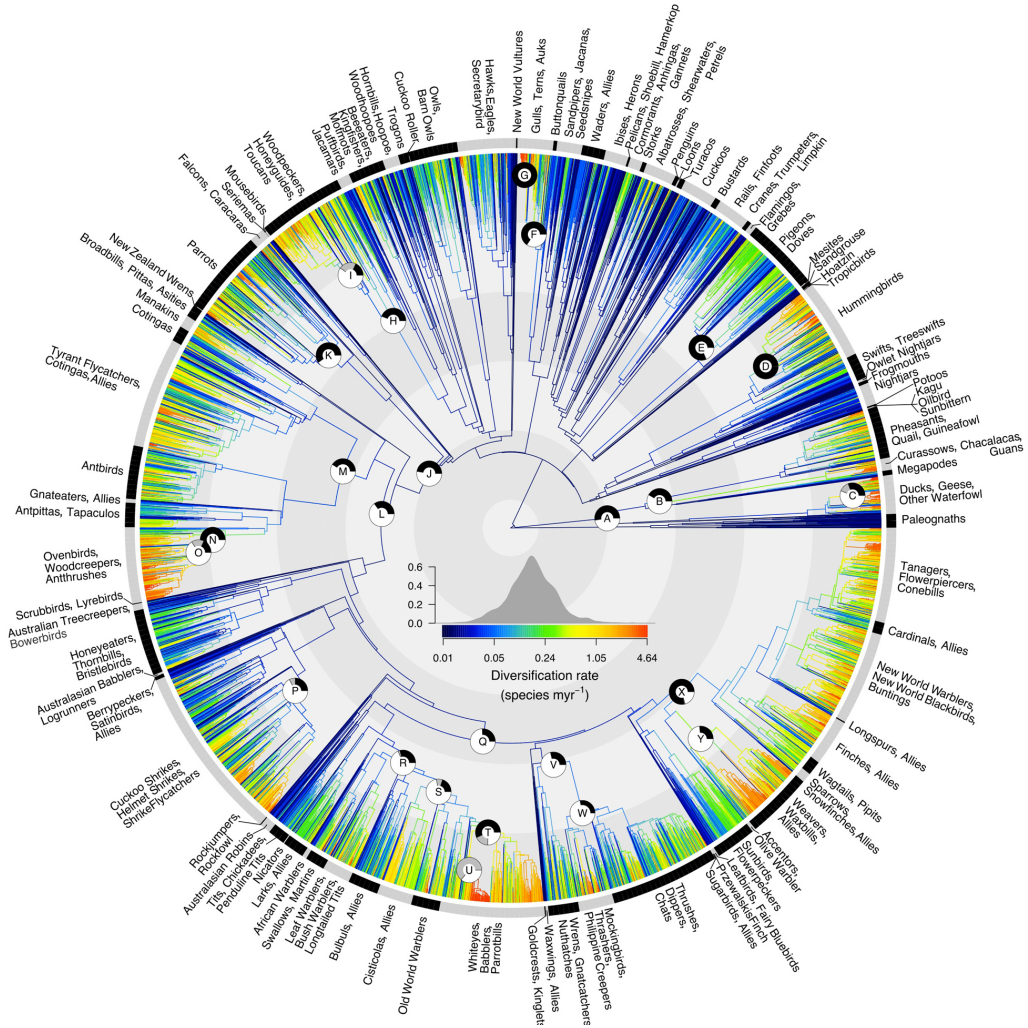


Distribution of 2,000 trees drawn at random from Jetz et al., 2012

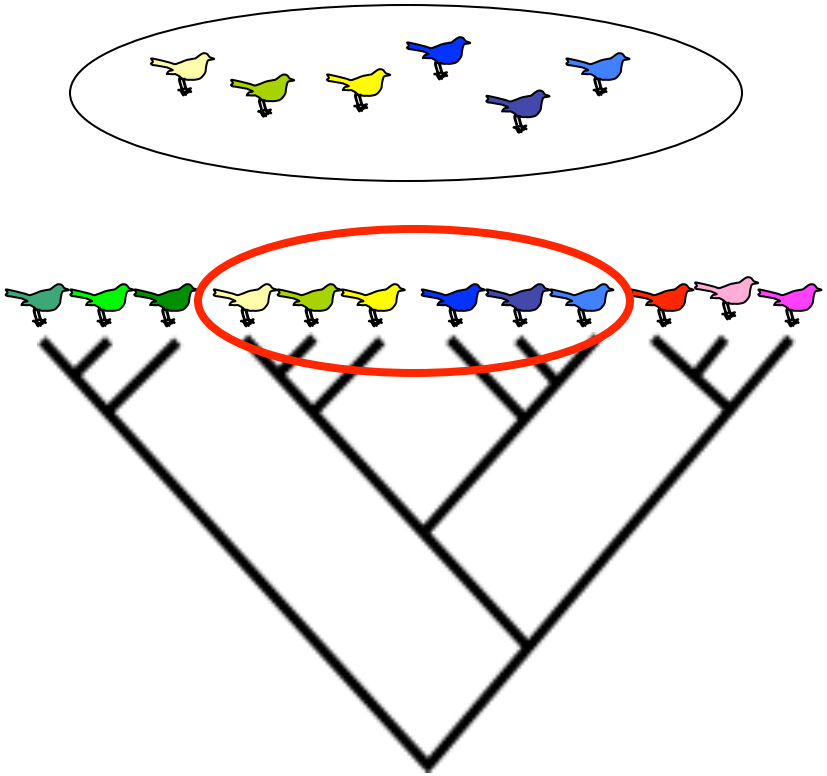
The global diversity of birds in space and time

W. Jetz, G. H. Thomas, J. B. Joy, K. Hartmann & A. O. Mooers

nature

Assess phylogenetic structure with null model

Mean phylogenetic distance (MPD)
for all pairwise species
combinations in local community



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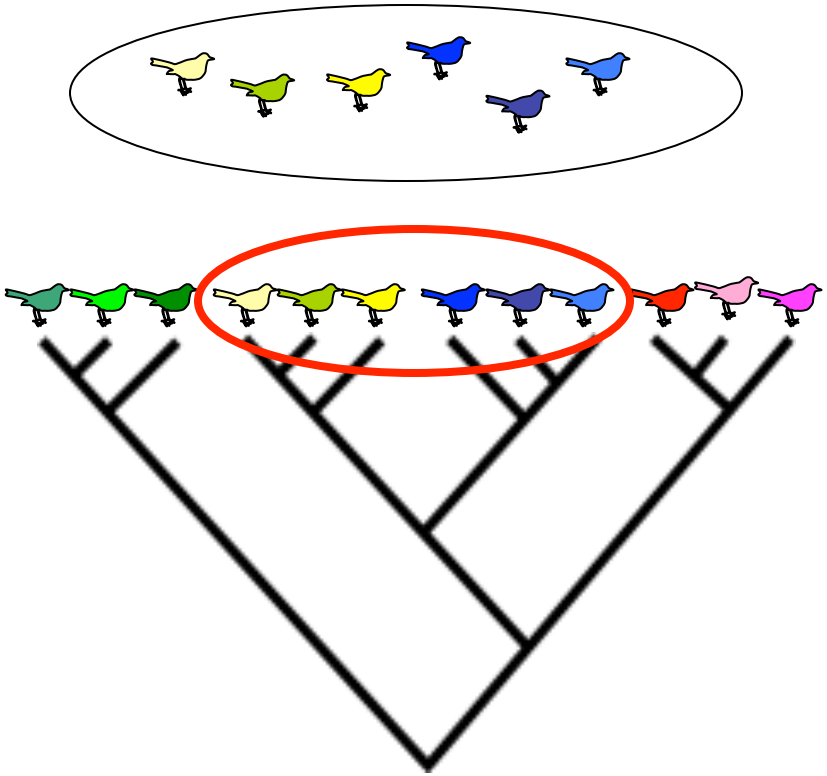
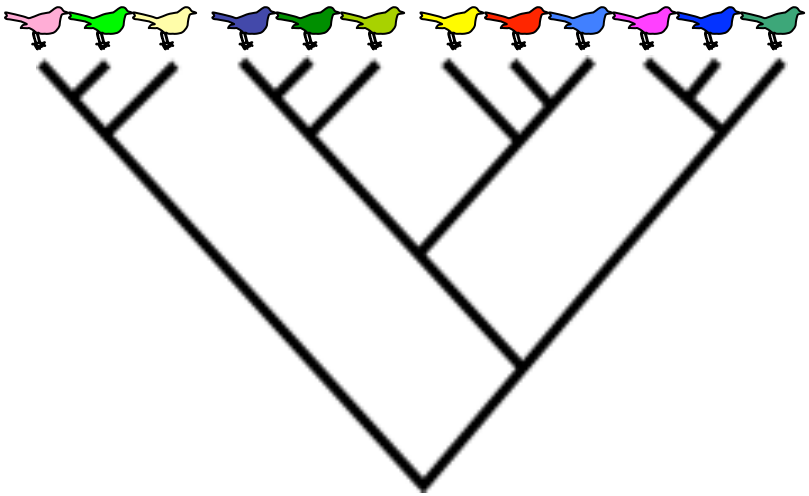


Randomize placement of species
and recalculate (1000's of times)



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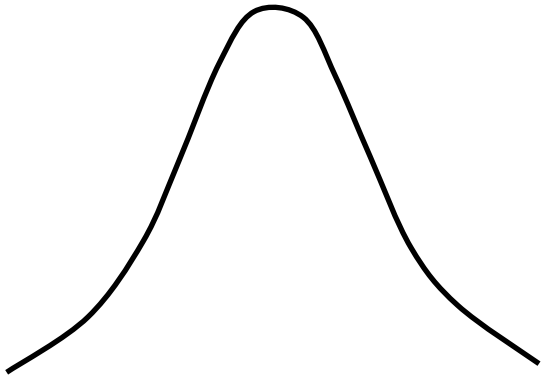

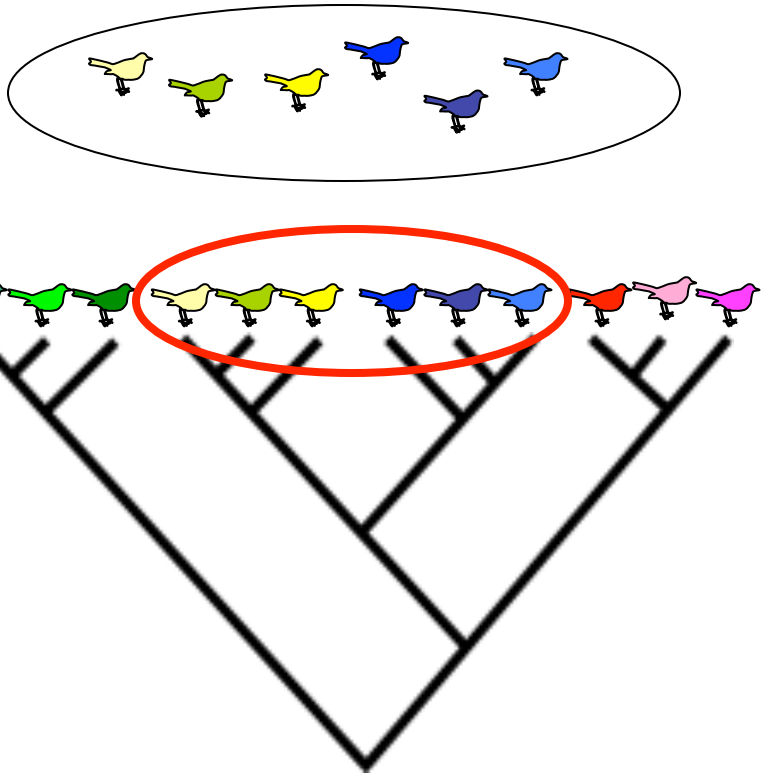

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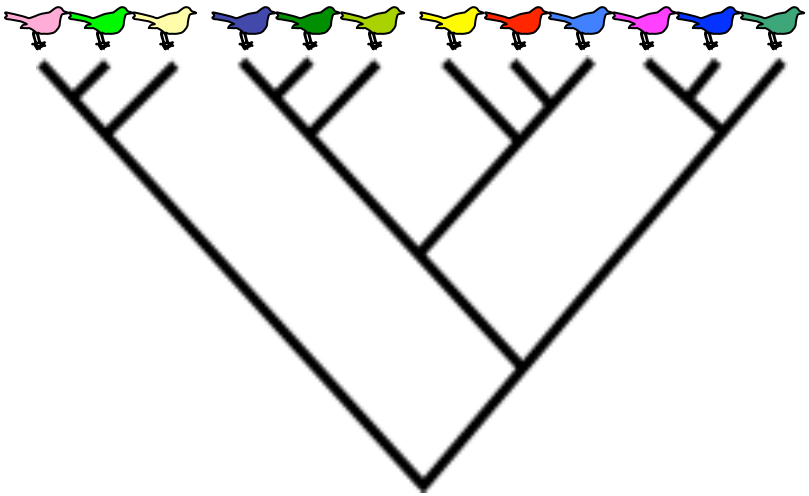
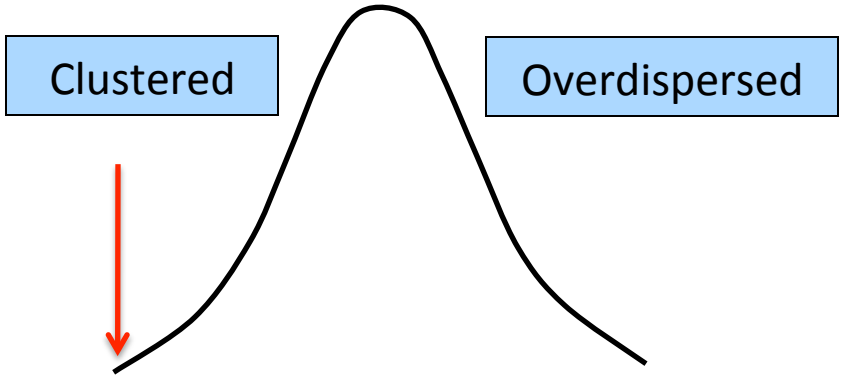
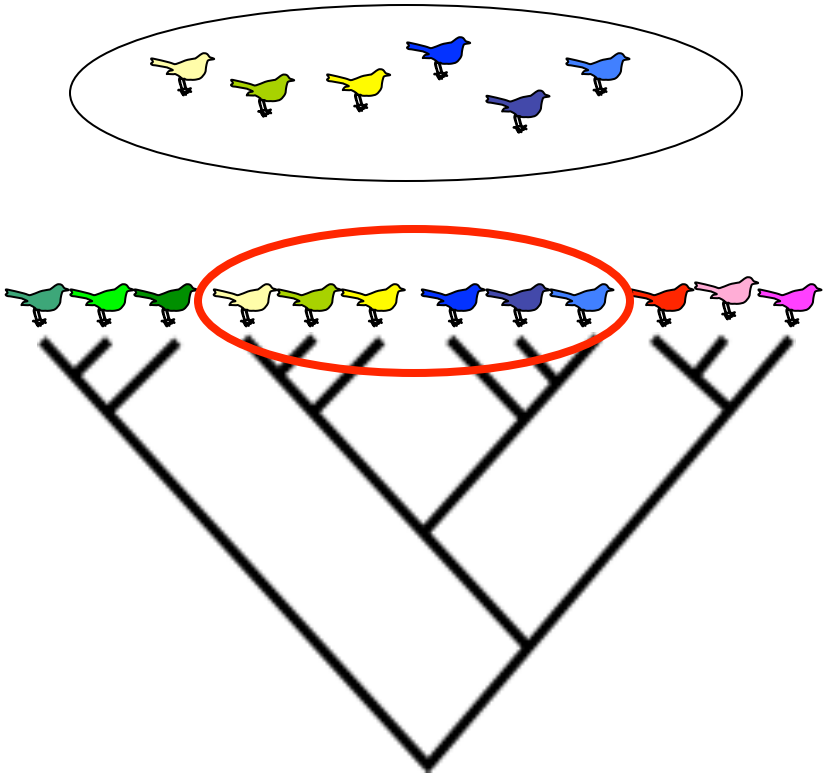


Assess phylogenetic structure with null model

Mean phylogenetic distance (MPD) for all pairwise species combinations in local community





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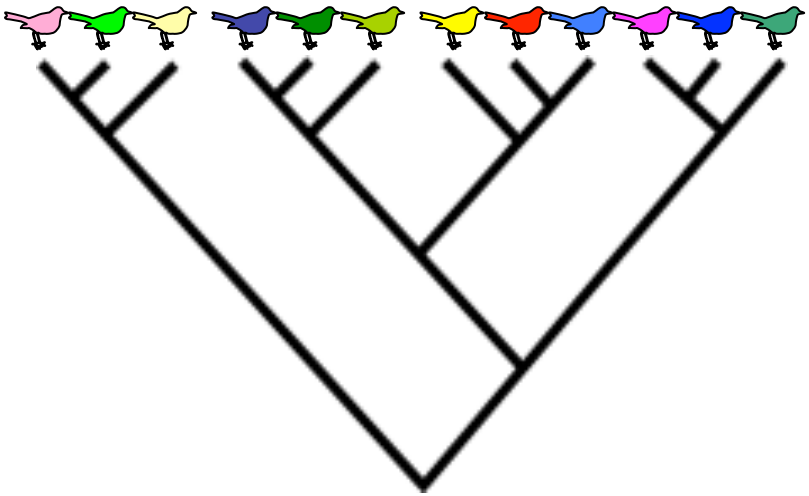
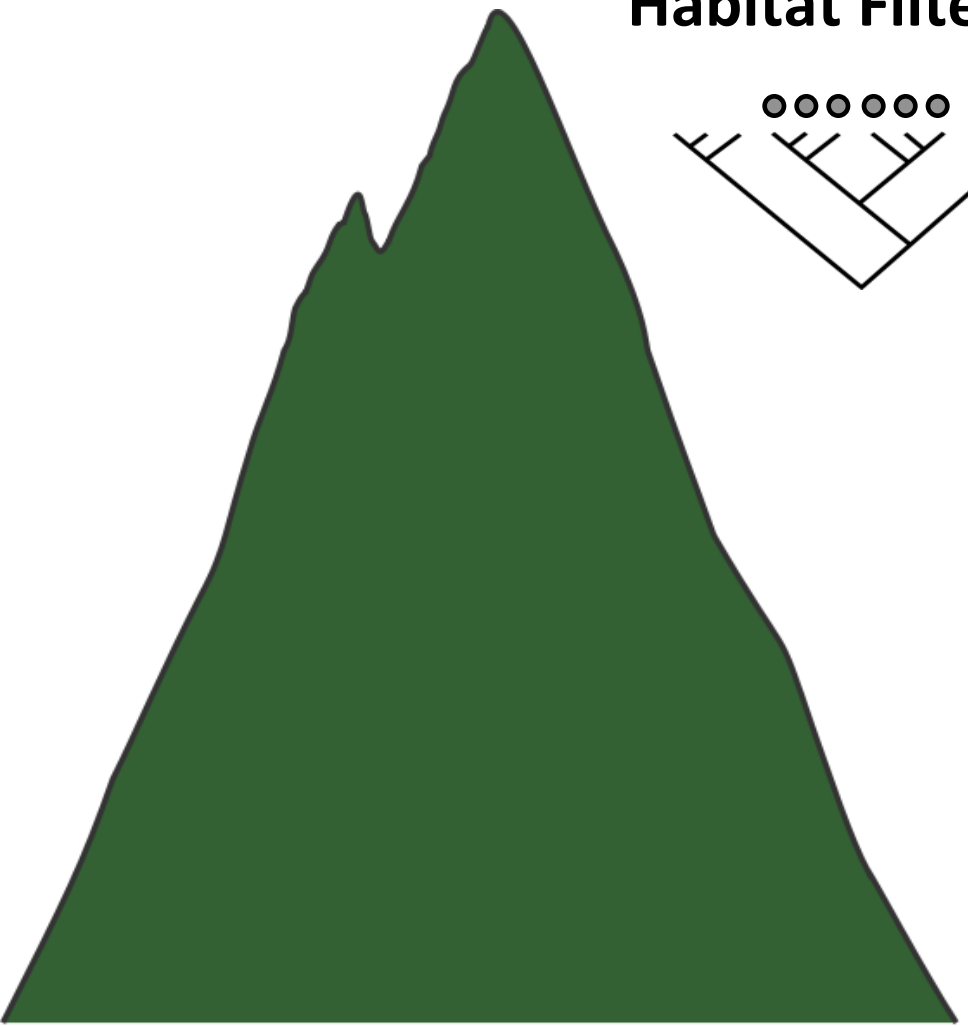


Prediction:
Overdispersion to phylogenetic clustering with elevation

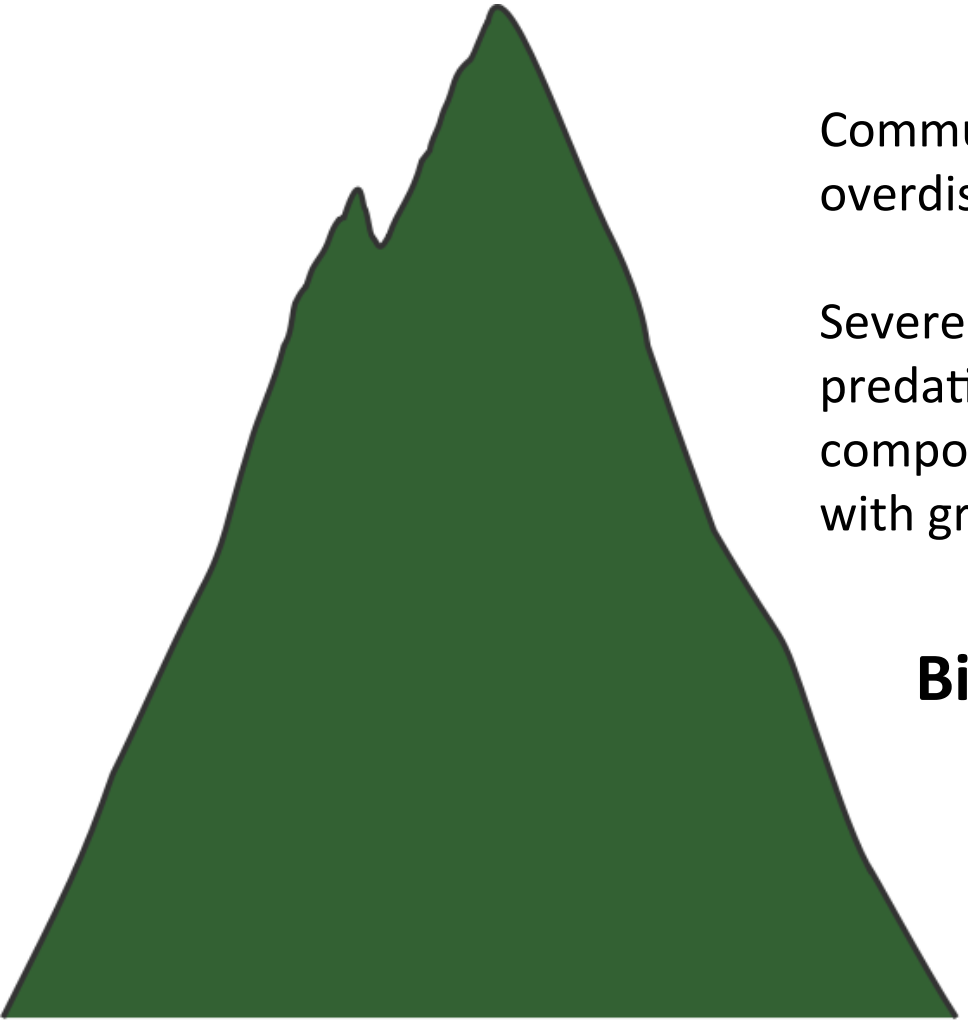


Habitat Filtering

Communities at high elevations should be clustered

Extreme abiotic conditions should pose a strong habitat filter, resulting in communities composed of similar species, with more similar traits

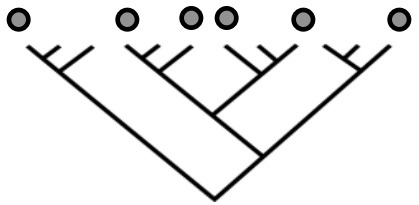
Prediction:
Overdispersion to phylogenetic clustering with elevation



Communities at low elevations should be overdispersed

Severe biotic pressures (like competition or predation) should result in communities composed of more distinct species, with greater differences in traits

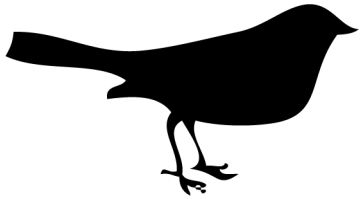
Biotic Interactions



Passeriformes

Thraupidae

Tyrannidae

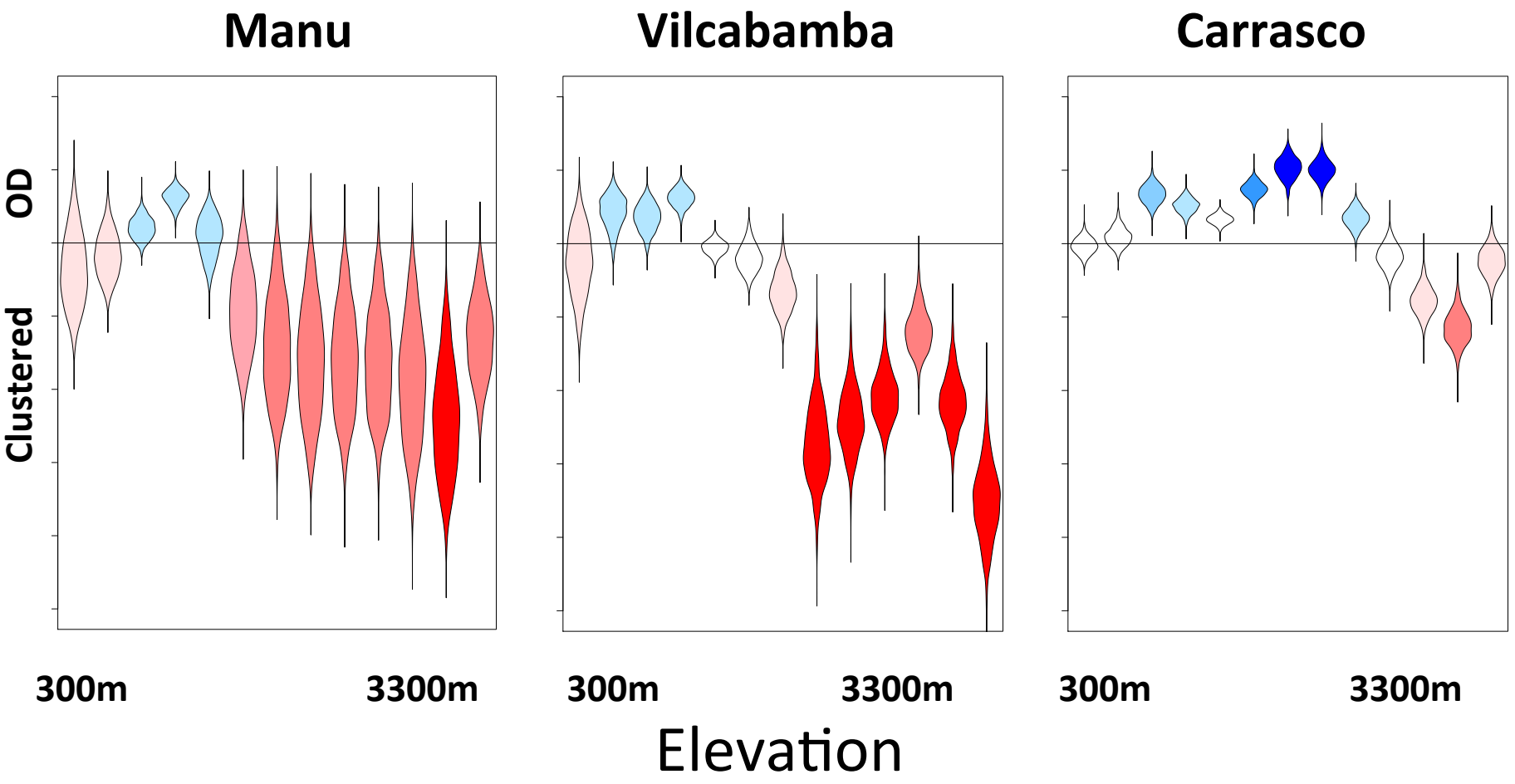


Thamnophilidae

Furnariidae

Trochilidae

Mean phylogenetic distance (MPD) plotted for diverse tropical bird families



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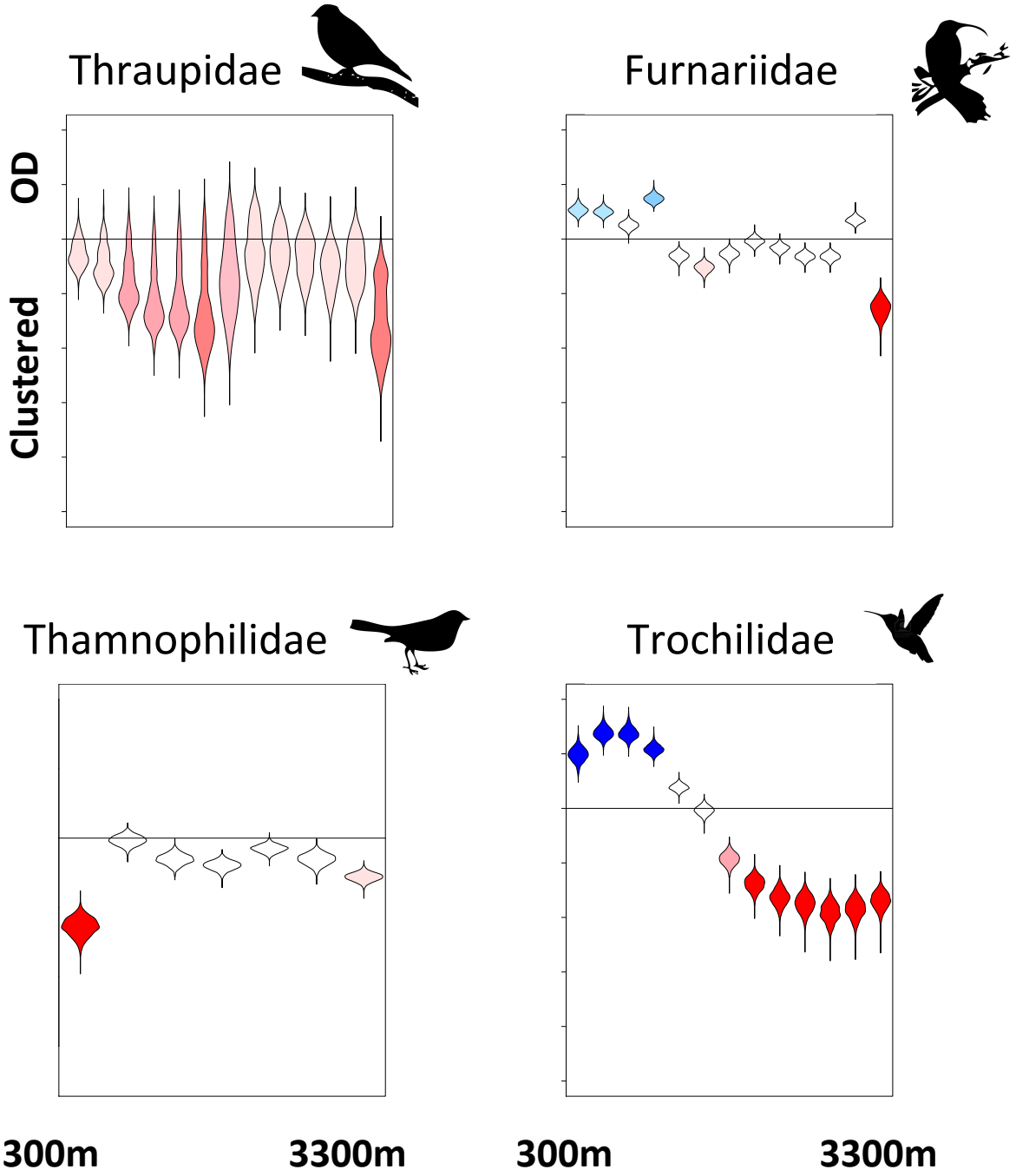
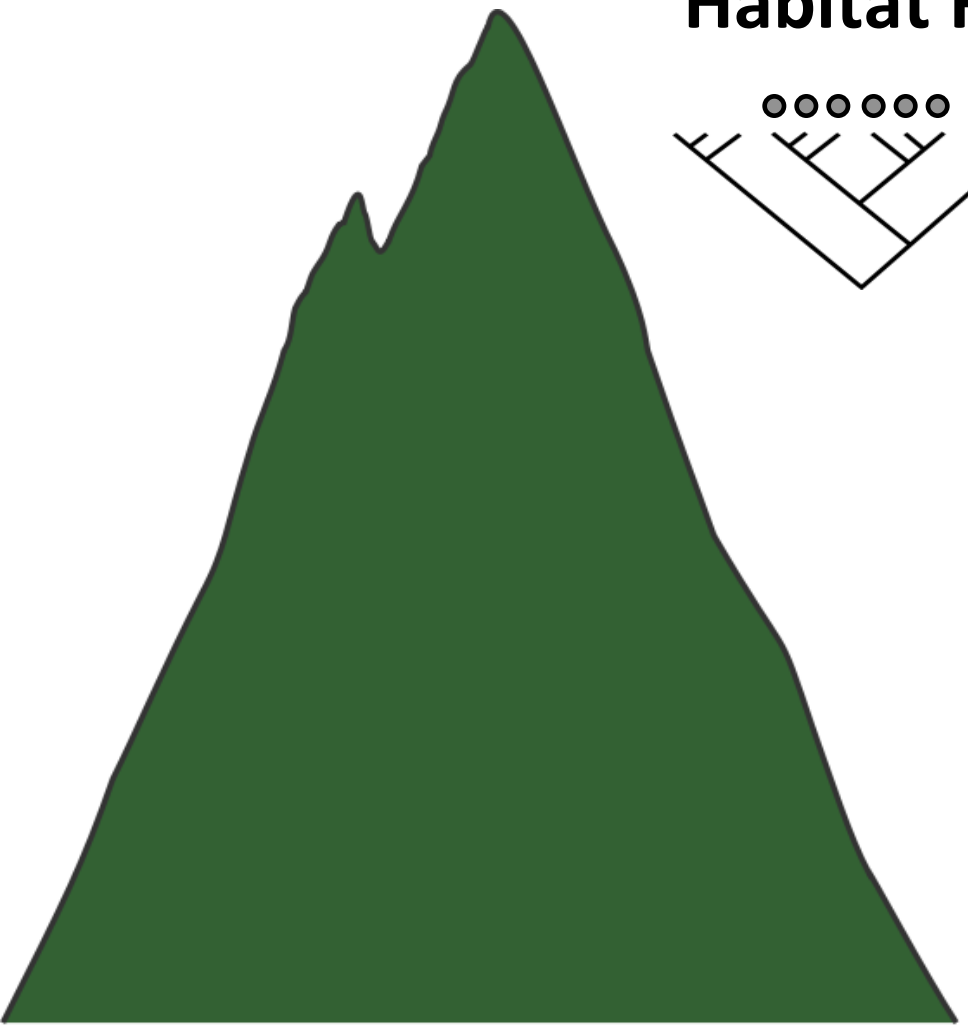
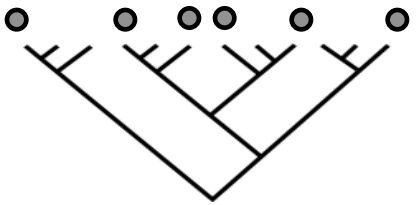


Overdispersion to phylogenetic clustering along the elevation gradient



Habitat Filtering

Biotic Interactions



Conclusions

Evidence for high elevation clustering for most family groups of Passerines and hummingbirds

Moderate over-dispersion in many lowland groups

What sorts of ecological or evolutionary processes would generate these patterns?

How could we test this more broadly?

Phylogenetics and Community Structure

References for this section:

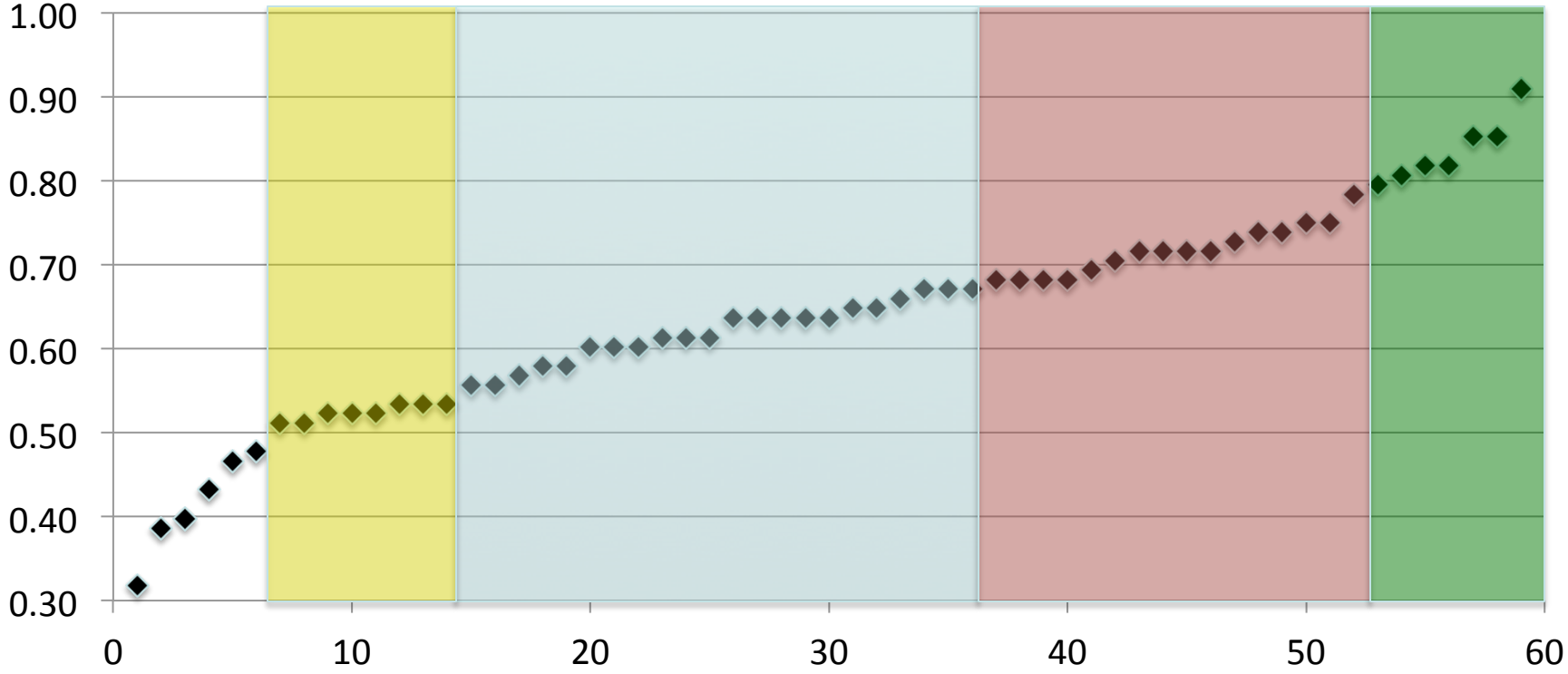
Cavender-Bares, J., Kozak, K. H., Fine, P. V., & Kembel, S. W. (2009) The merging of community ecology and phylogenetic biology. *Ecology letters*, *12*, 693-715.

Jetz, W., Thomas, G. H., Joy, J. B., Hartmann, K., & Mooers, A. O. (2012) The global diversity of birds in space and time. Nature, 491, 444-448.

Terborgh, J. (1971) Distribution on environmental gradients: theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. Ecology, 23-40.

Webb, C. O., Ackerly, D. D., McPeek, M. A., & Donoghue, M. J. (2002) Phylogenies and community ecology. Annual review of ecology and systematics, 475-505.

Midterm exam mark distribution



Average: 28/44 (64%)