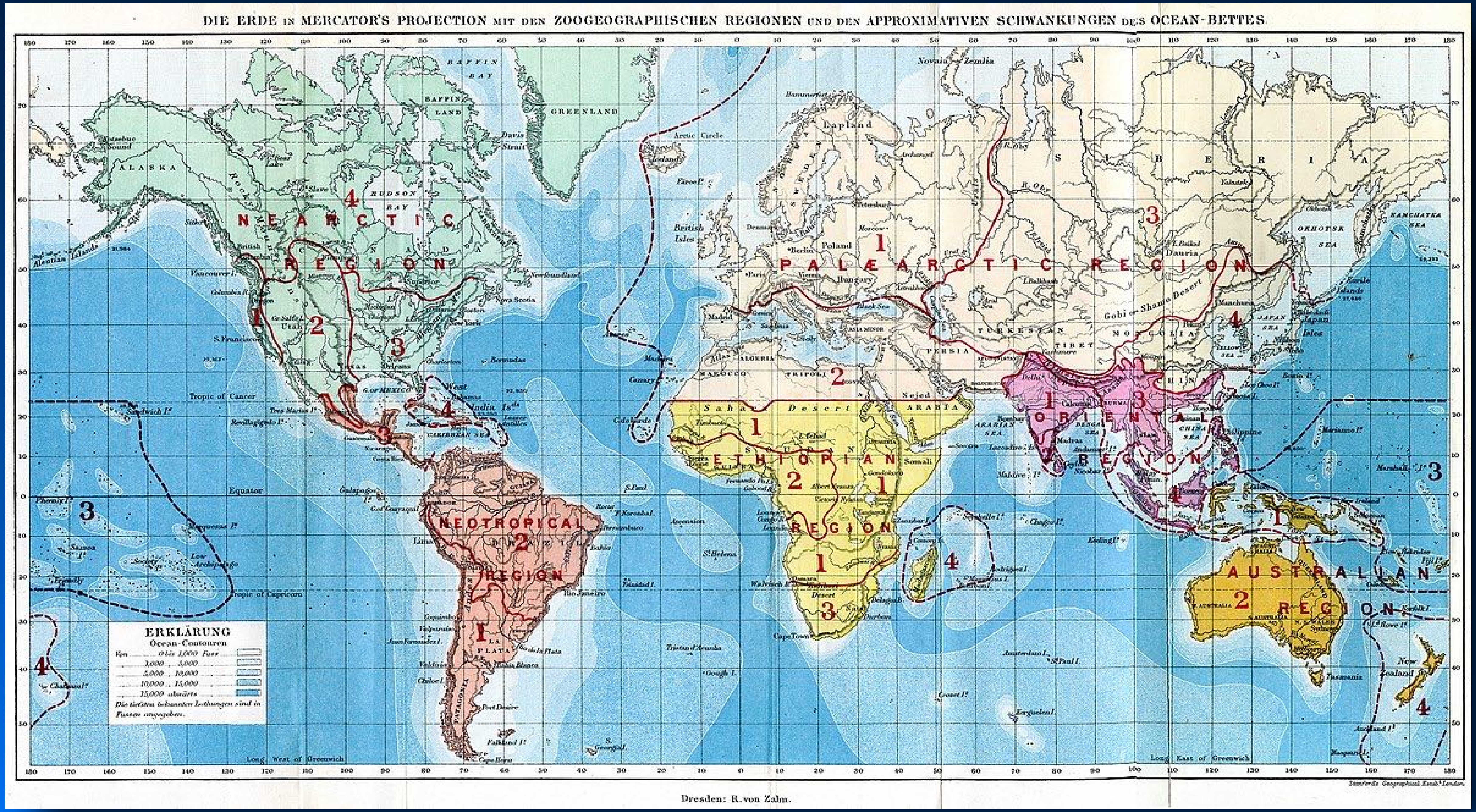
NJU Course

Principles of Paleobiology

Paleobiological Paleobiogeography



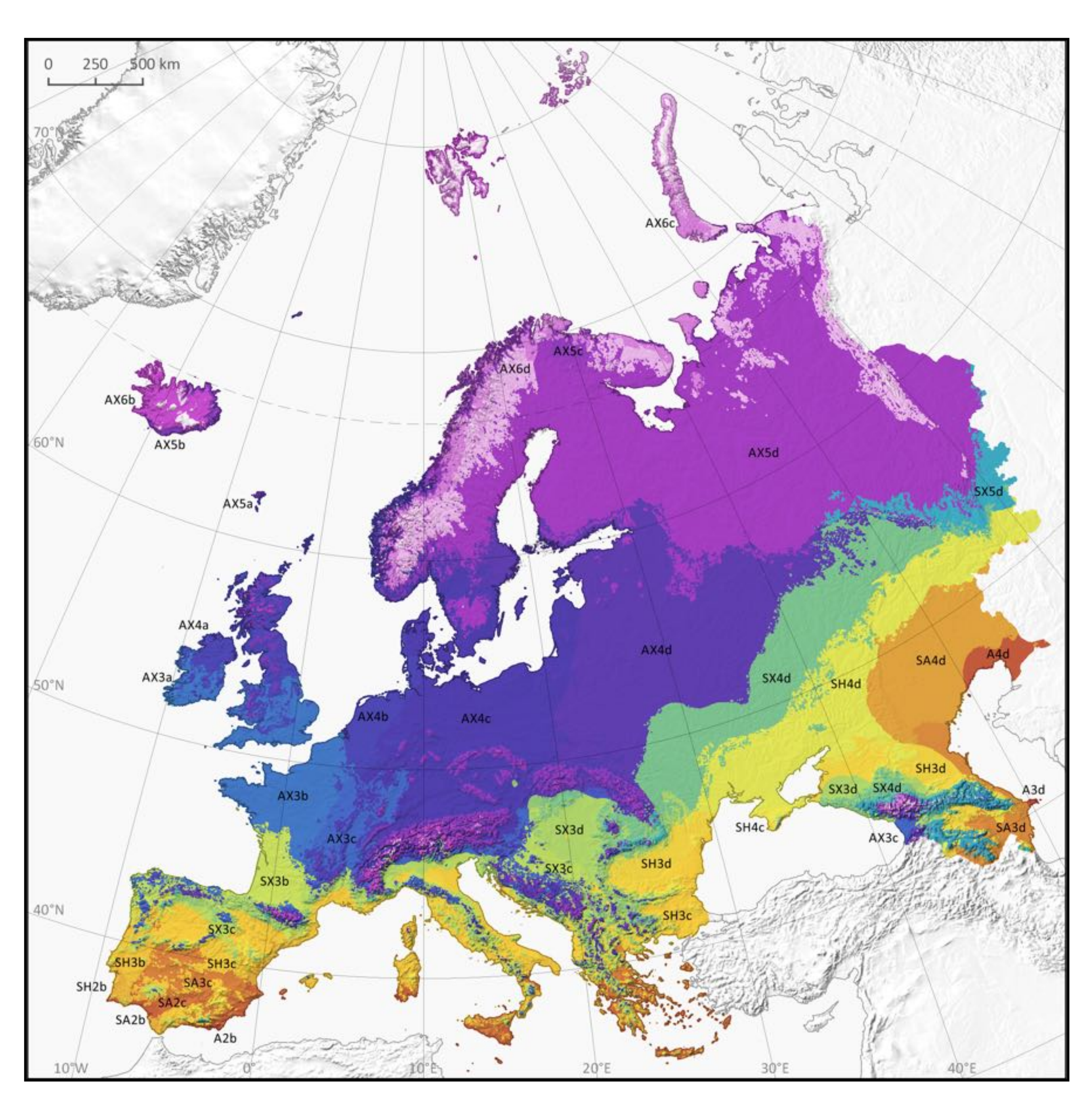
Paleobiological Paleobiogeography

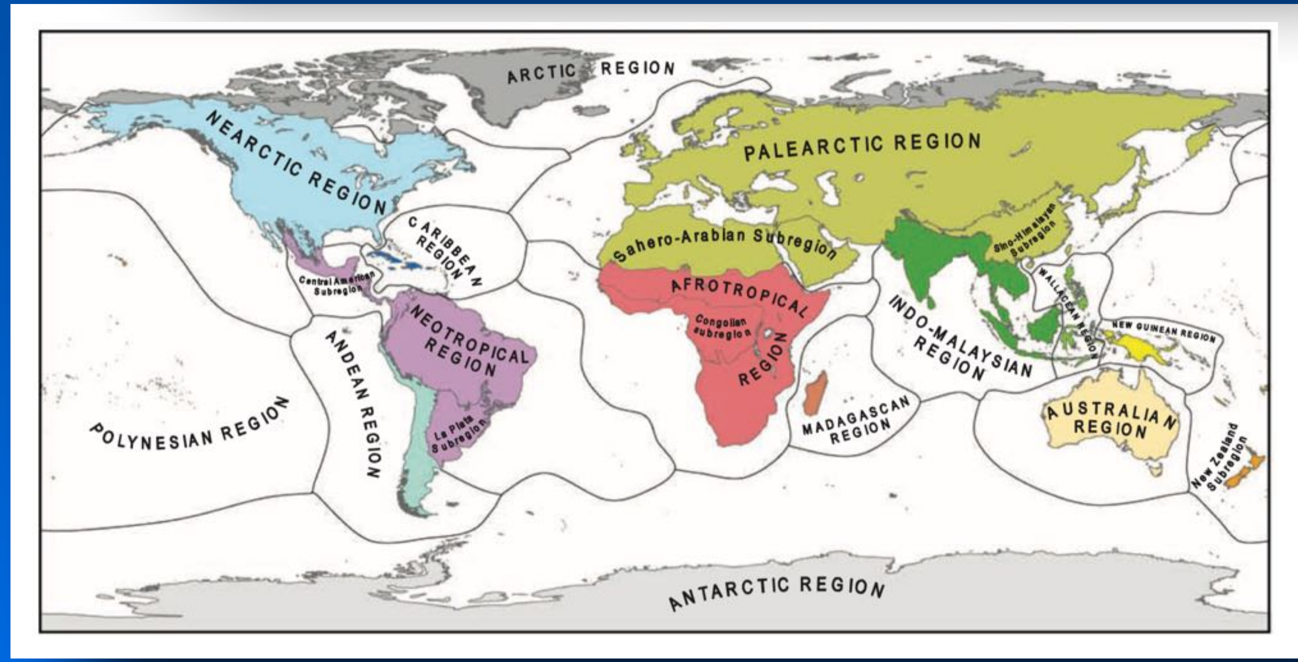
Definitions

Biogeography - The study of the distribution and abundance of species, populations, comunities, biomes and ecosystems in geographic space.

Paleobiogeography - Biogeography studies in the additional context of geological time.

- Taxonomic Biogeography
  - Phytobiogeography - the study of the geographic distribution of plant species in the Recent, in historical times, and in the geological past.
  - Zoobiogeography - the study of the geographic distribution of animal species in the Recent, in historical times, and in the geological past.





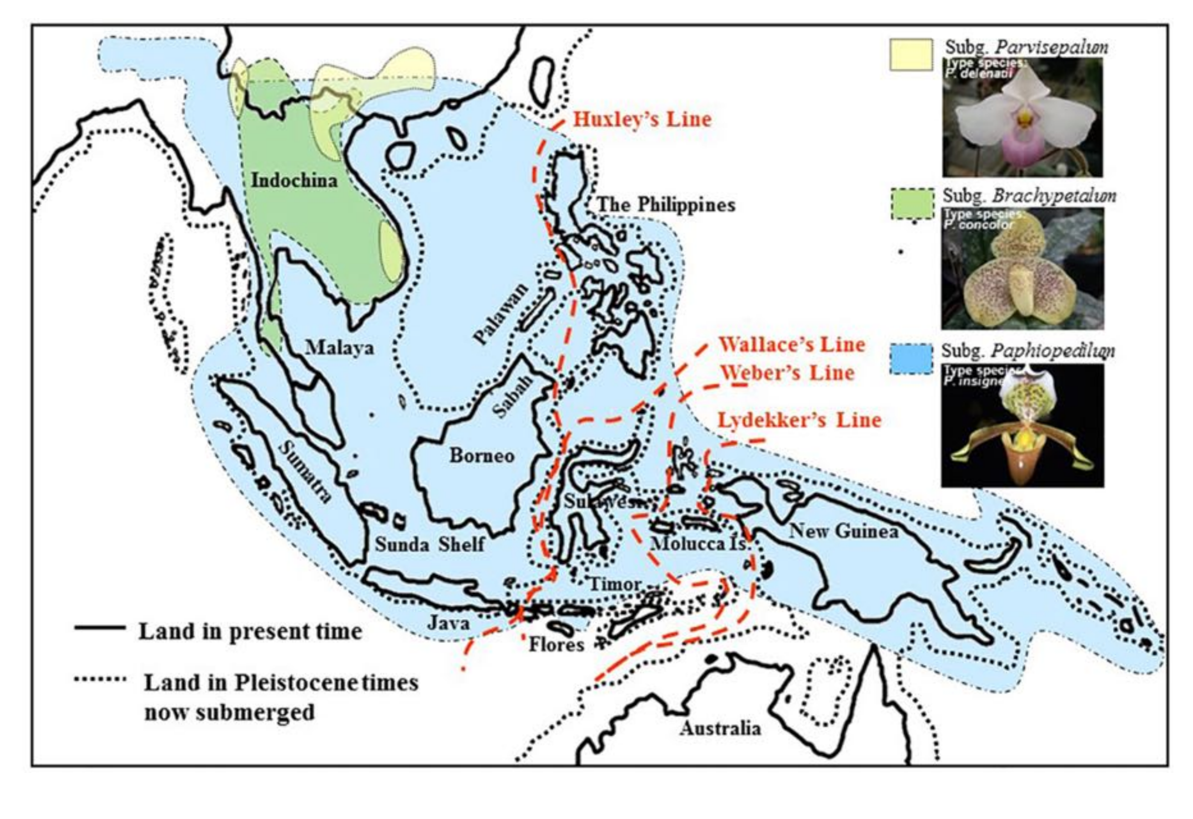
Maps from Botti (2018, top) and Proches & Ramdhani (2012, bottom)

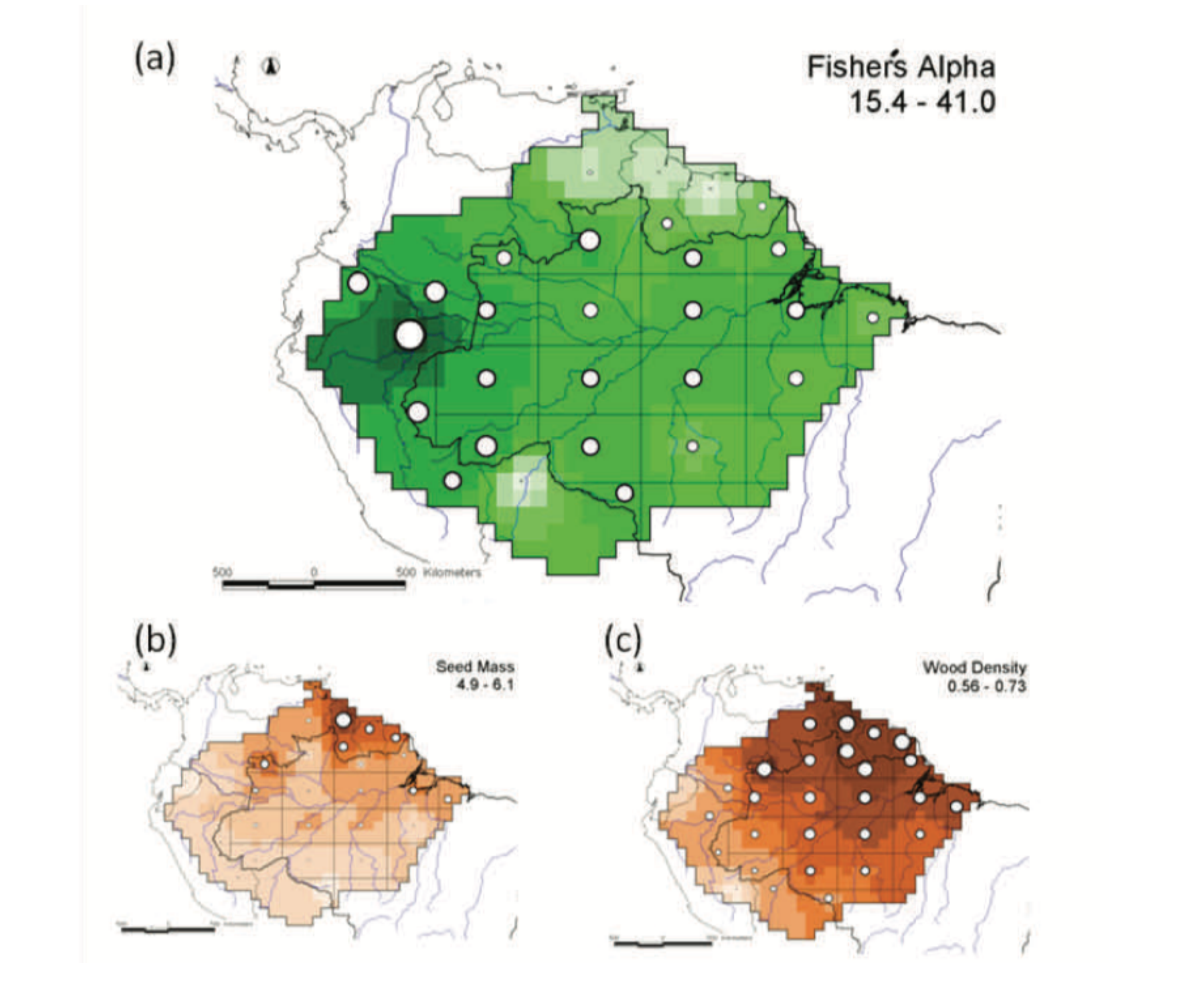
Paleobiological Paleobiogeography

Definitions

(Paleo)Biogeography - The study of the distribution and abundance of species, populations, comunities, biomes and ecosystems in geographic space (and through geological time).

- Subfields
  - Historical Biogeography (paleobiogeography) - the study of the distribution of species in the geological past.
  - Ecological Biogeography - the study of the factors responsible for the spatial distribution of species.
  - Conservation Biogeography - the study of how the spatial distribution of species has changed in historical times and what can be done to correct or mitigate human influence on nature.





Maps from Tsai et al. (2020, top) and Malhado et al. (2013, bottom)

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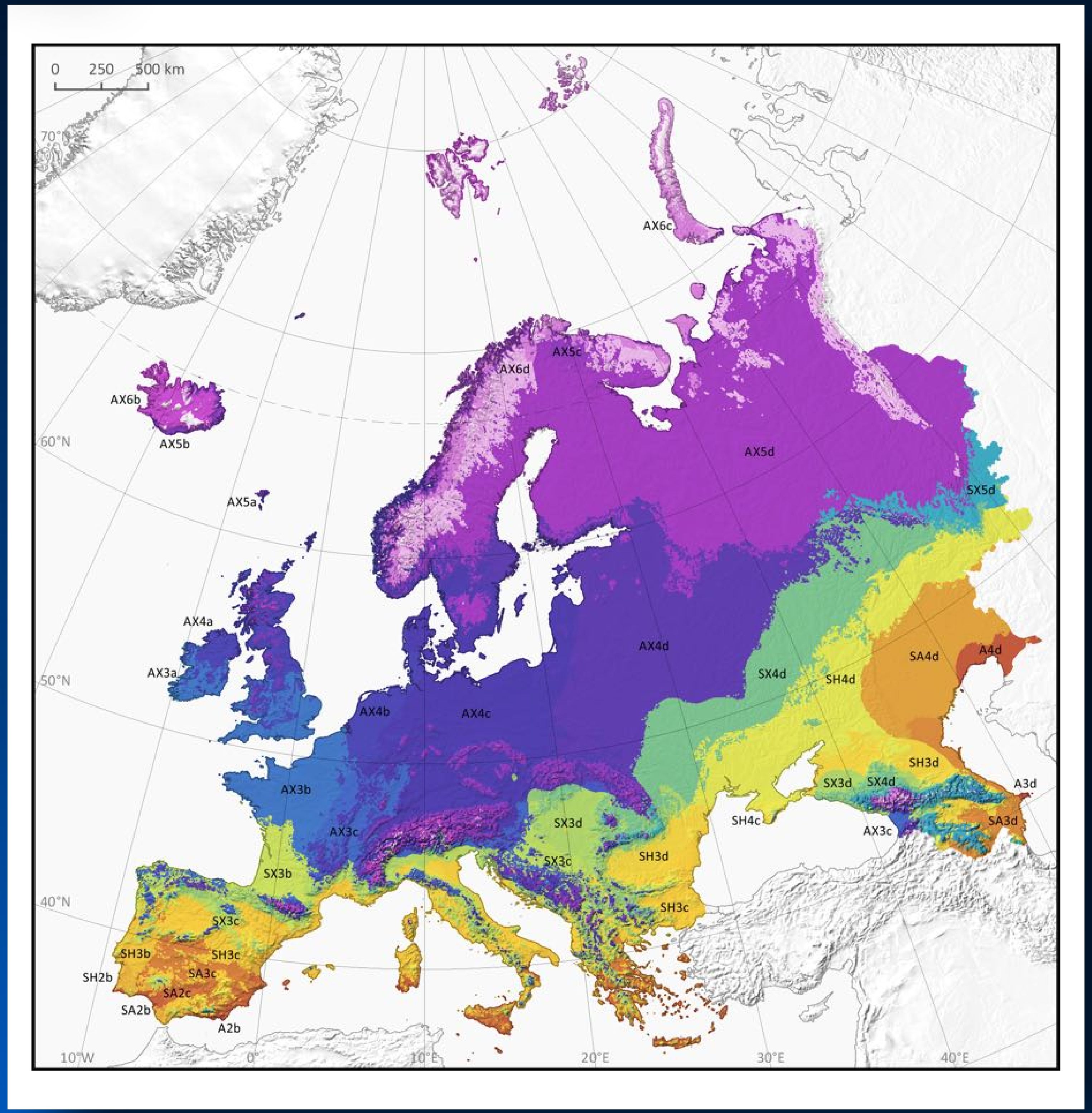
Biogeographic Taxonomy

The hierarchical structure of biogeographic organization differs from the ecological structure insofar as it is based on a complex mixture of physical and biotic defining criteria.

- Biogeographic Structure
  - Realm - spatially, the broadest subdivision of biogeographic organization based on distributional patterns of species; typically divided into provinces, bioregions and ecoregions.
  - Province - large regions in which species have been evolving in isolation for a long period of time and that are separated from other such regions by barriers to migration (e.g., oceans, deserts, mountains).
  - Biome - a large, non-unique collection of species occupying a major habitat.



Map from Botti (2018)

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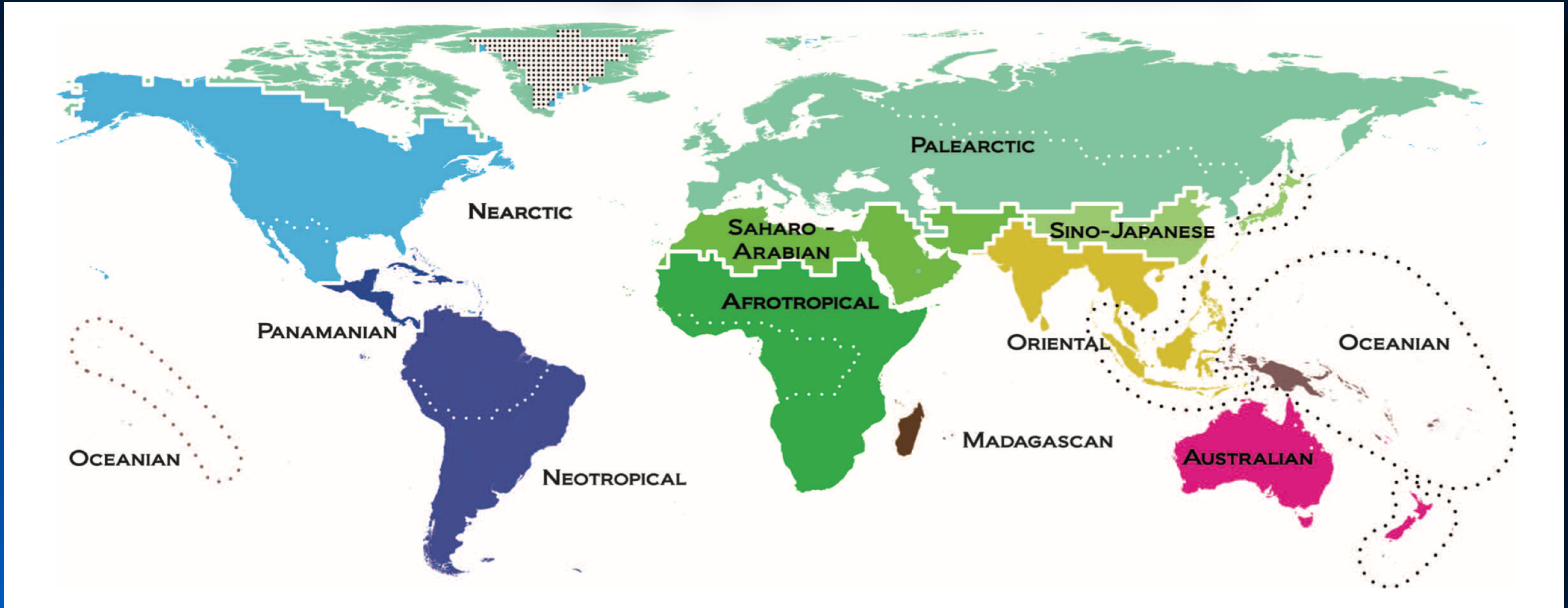
Global Biogeographic Realms (Recent)



In 2013 Wallace's system of the subdivision of the globe into seven biogeographic realms was revaluated in light of the evidence that has accounted over the 20th century. The result of this refinement was an increase in the number of realms to 11.

Map from Holt et al. (2013)

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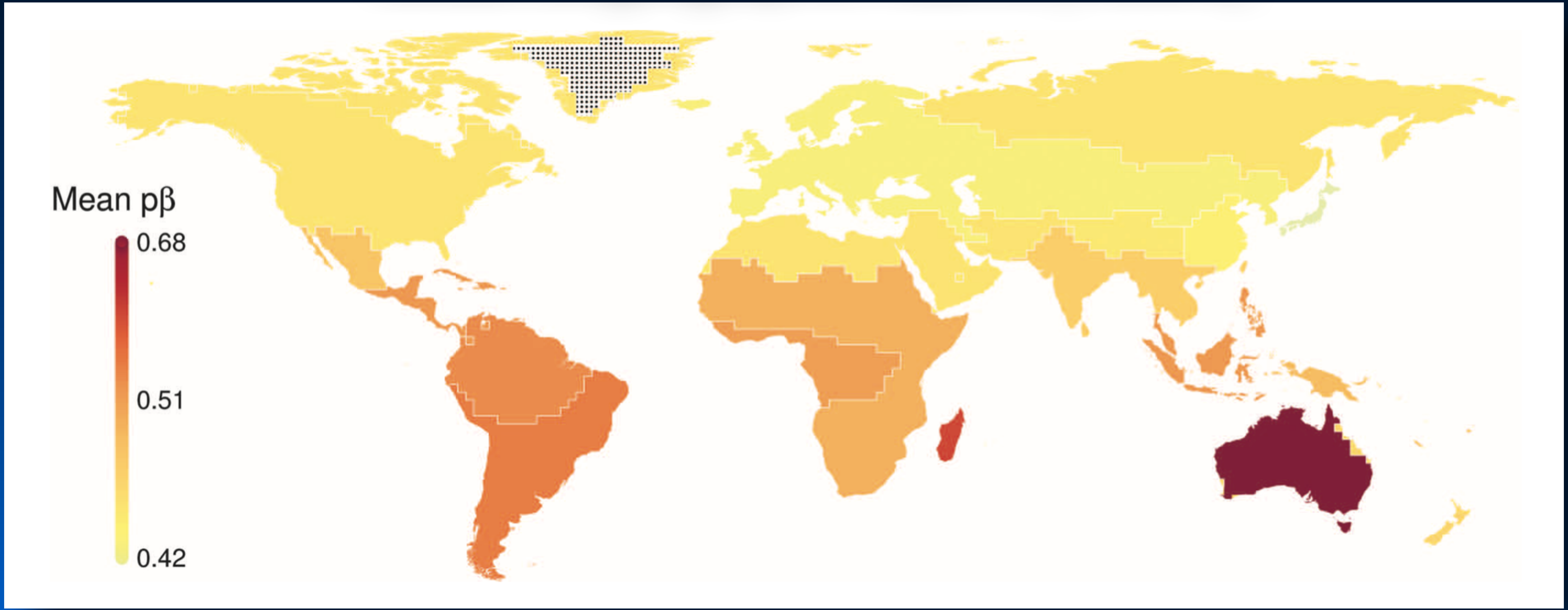
Global Biogeographic Realms (Recent)



A tabulation of 21,037 species distributions compiled by the Holt et al. (2013) research team allowed level of evolutionary uniqueness, or endemism, to be estimated for each biogeographic province. These data suggest the Australian province is the most unique, the Palearctic the least.

Map from Holt et al. (2013)

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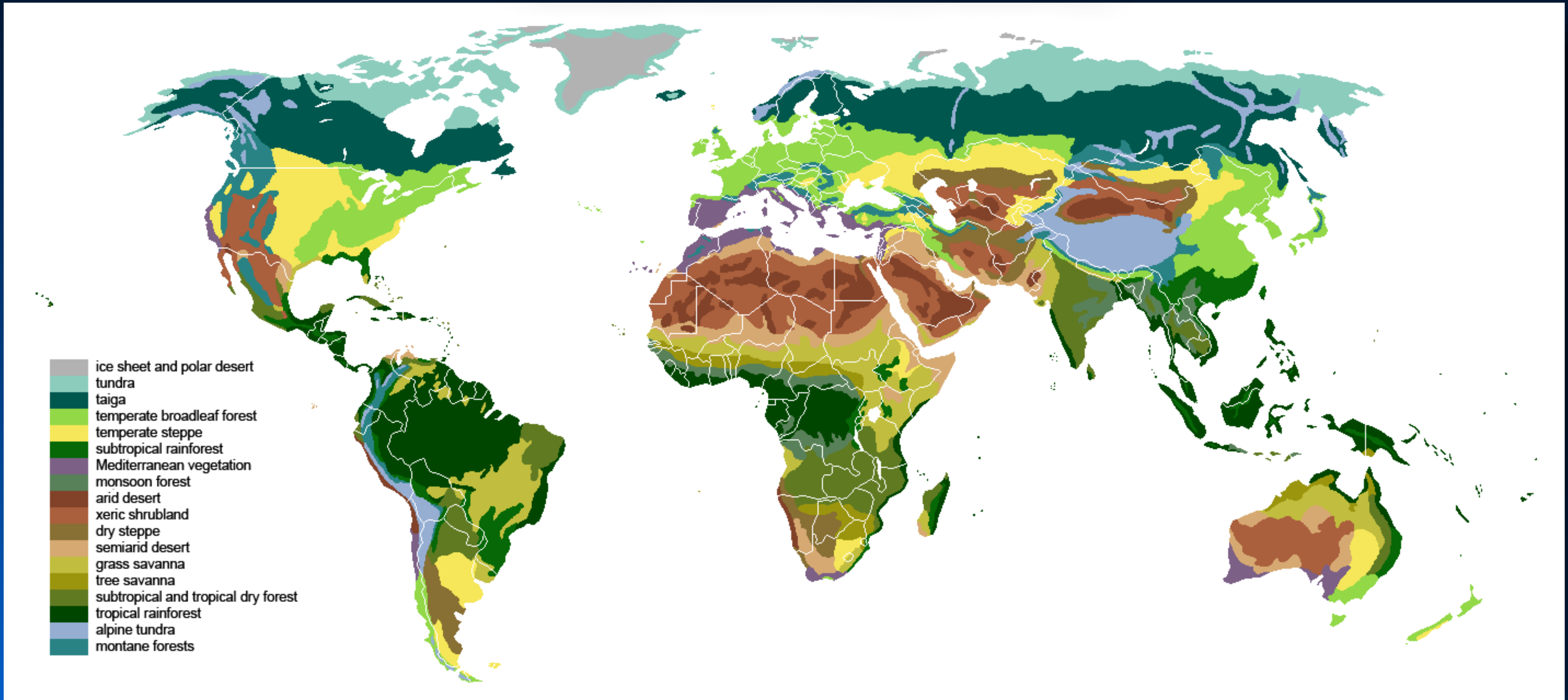
Global Biomes (Recent)



Globally there are 18-20 generally recognized biomes or habitat types. Habitats represent areas of similar physical attributes and biotic resources available to species. Ecologically species subdivide habitats into niches in order to reduce inter-species competition.

Map from Koistinen (2007)

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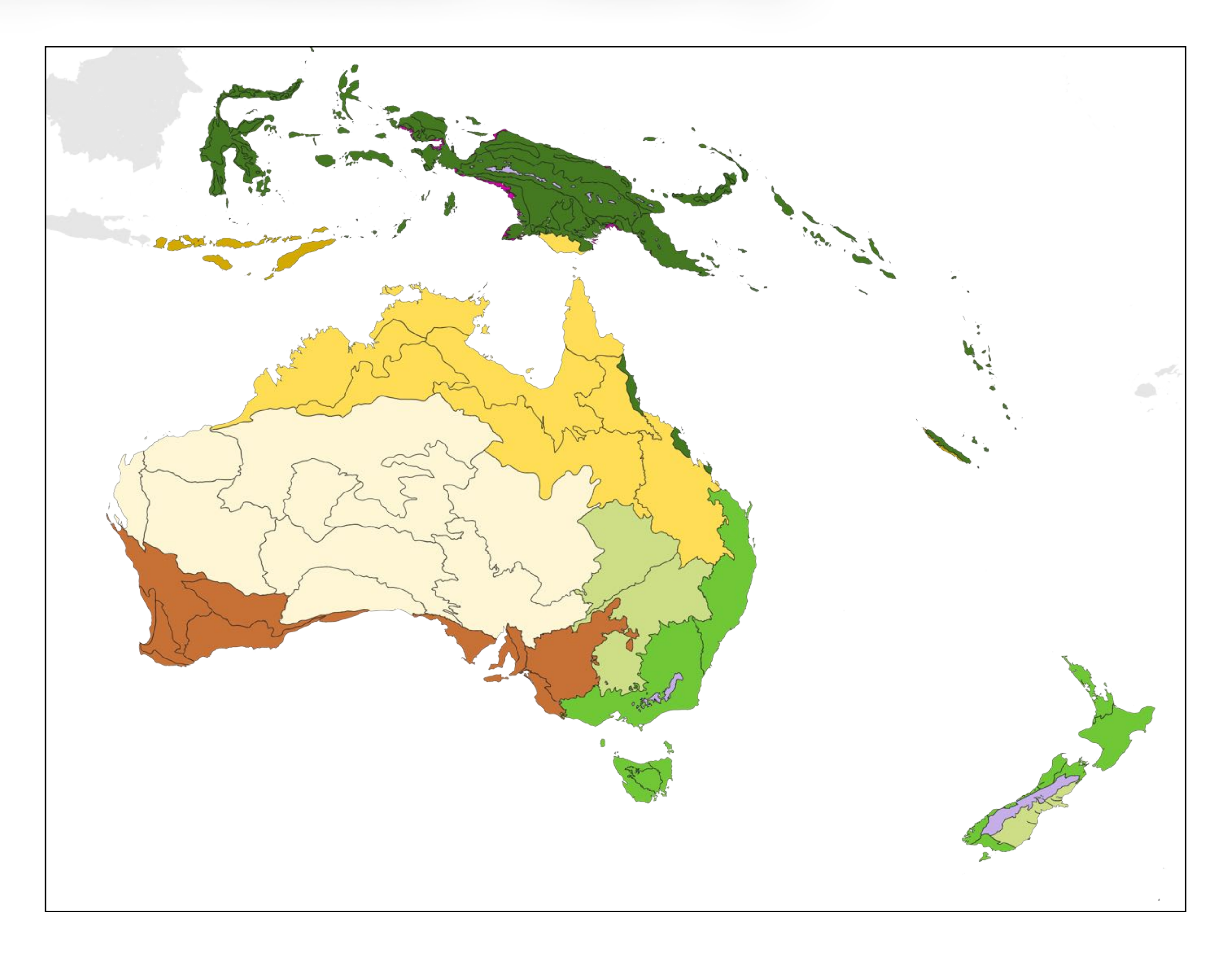
Biogeographic Provinces (Australasian Realm)

Each major biogeographic realm is subdivided into a series of provinces that are further subdivided into bioregionsand/or ecoregions



- Tropical/subtropical moist forests
- Tropical/subtropical dry for-ests
- Tropical/subtropical grasslands and savanahs
- Temperate forests
- Temperate grasslands and savanahs
- Flooded grasslands and savannas
- Montane grasslands
- Mediterranean woodlands
- Deserts
- Mangrove swamps

Map from Terpsichores (2012)

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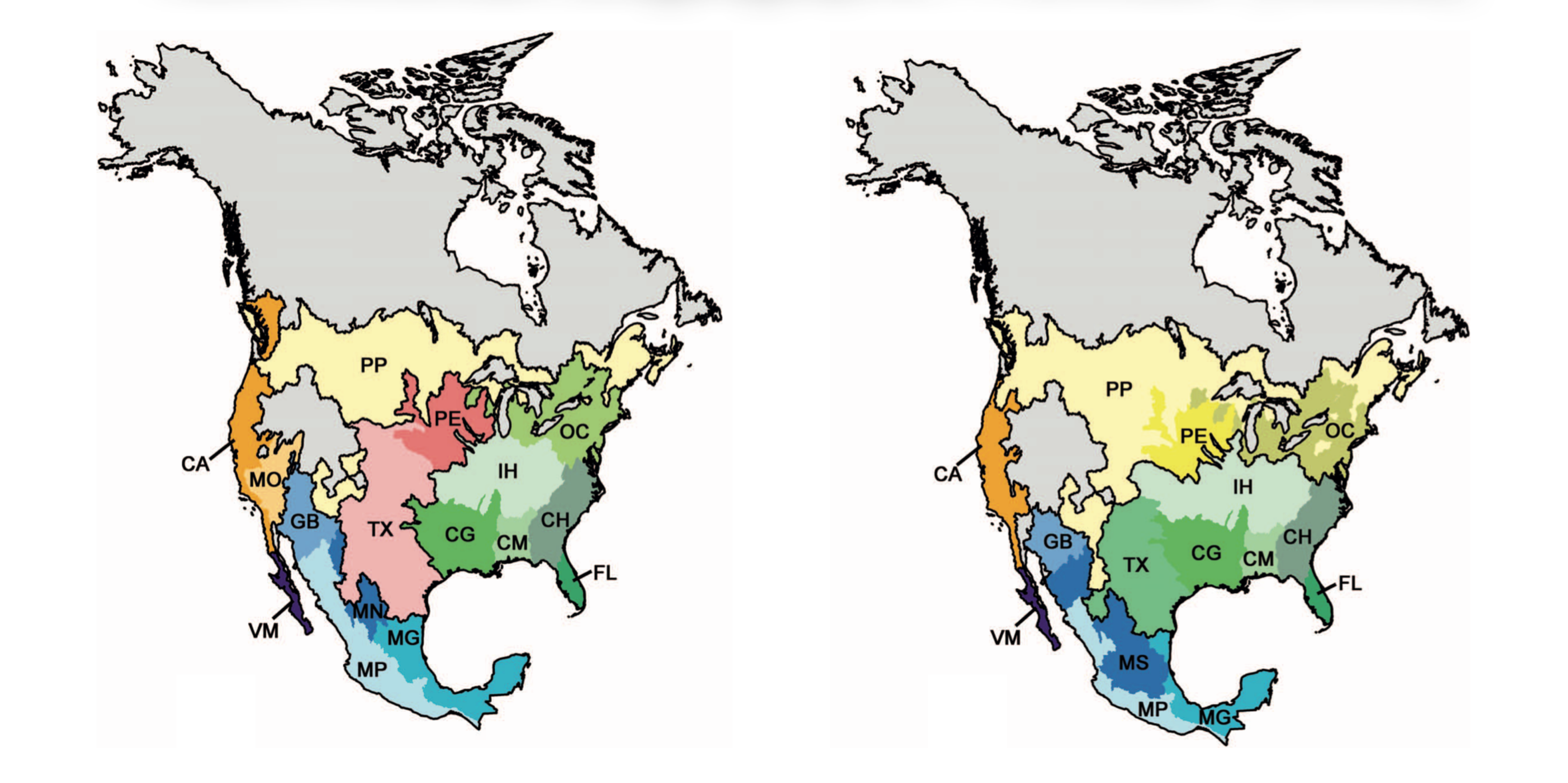
North American Biogeographic "Provinces" (Turtles)



Biogeographic classifications can also be produced for any taxonomic group.

Maps from Ennen et al. (2017)

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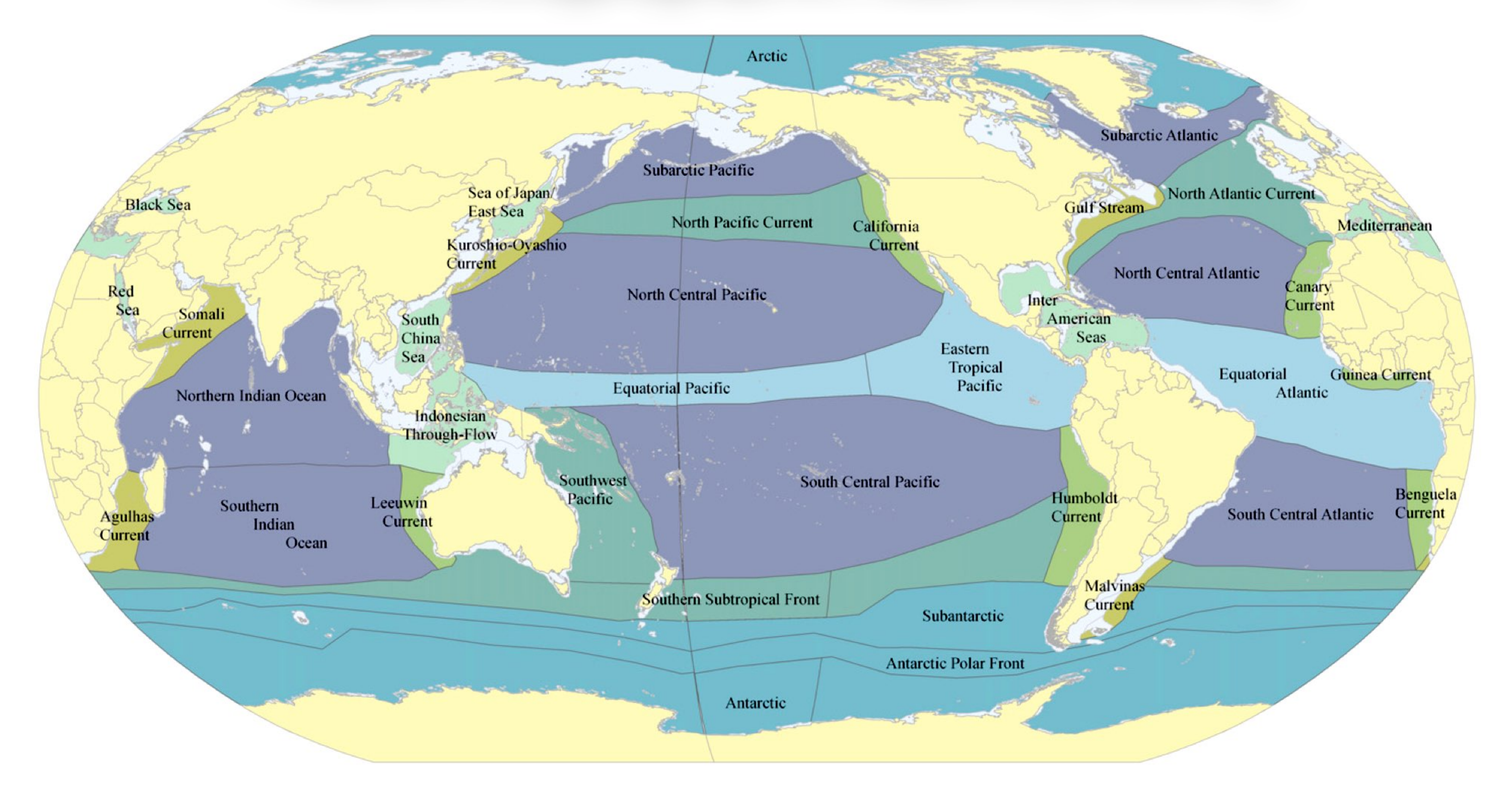
Marine Biogeographic Realms (Recent)



Pelagic biogeographic realms (colored) and provinces (labeled).

Map from Spalding et al. (2012)

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Assessing Patterns of Biogeographic Similarity

Jaccard Index

$$J = A \cap B / A \cup B$$

Raup & Crick Coefficient

$$RSCI_{AB} = \frac{A!B!(N-A)!(N-B)!}{N!k!(A-k)![(N-B)-(N-k)]!(B-k)!}$$

Euclidean Distance

$$d_{A,B} = \sqrt[2]{\sum_{i=1}^{n}(A_i - B_i)^2}$$

Turtle province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
All															
1. California	0														
2. Central Gulf Coastal Plain	1.000	0													
3. Chesapeake–Apalachicola	0.977	0.483	0												
4. Choctawhatchee–Mobile–Pascagoula	0.997	0.344	0.371	0											
5. Florida Peninsula	1.000	0.606	0.353	0.490	0										
6. Gila–Bouse	1.000	0.982	1.000	1.000	1.000	0									
7. Interior Highland	0.966	0.359	0.491	0.462	0.696	0.985	0								
8. Mesa del Norte–Mesa Central	0.979	0.956	0.972	0.996	1.000	0.901	0.932	0							
9. Méxican Gulf Coast	1.000	0.911	0.921	0.926	0.916	1.000	0.900	0.918	0						
10. Méxican Pacific Coast	1.000	0.995	1.000	1.000	1.000	0.954	0.997	0.926	0.915	0					
11. Mojave	0.730	1.000	1.000	1.000	1.000	0.925	1.000	1.000	1.000	1.000	0				
12. Ohio–Chesapeake–Merrimack	0.955	0.694	0.545	0.686	0.678	1.000	0.476	0.949	0.922	1.000	1.000	0			
13. Pluvial–Proglacial	0.894	0.910	0.818	0.905	0.908	0.999	0.739	0.910	0.997	1.000	1.000	0.624	0		
14. Prairie	0.950	0.598	0.749	0.723	0.874	0.960	0.458	0.889	0.975	0.994	1.000	0.535	0.614	0	
15. Texas Coast–Southern High Plains Rio Grande Embayment–Burgos Basin	0.982	0.568	0.701	0.678	0.840	0.947	0.542	0.798	0.902	0.984	1.000	0.718	0.777	0.516	0
16. Vizcaino–Magdalena	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.985	1.000	1.000	1.000	1.000	1.000

Data from Ennen et al. (2017)

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Assessing Patterns of Biogeographic Similarity

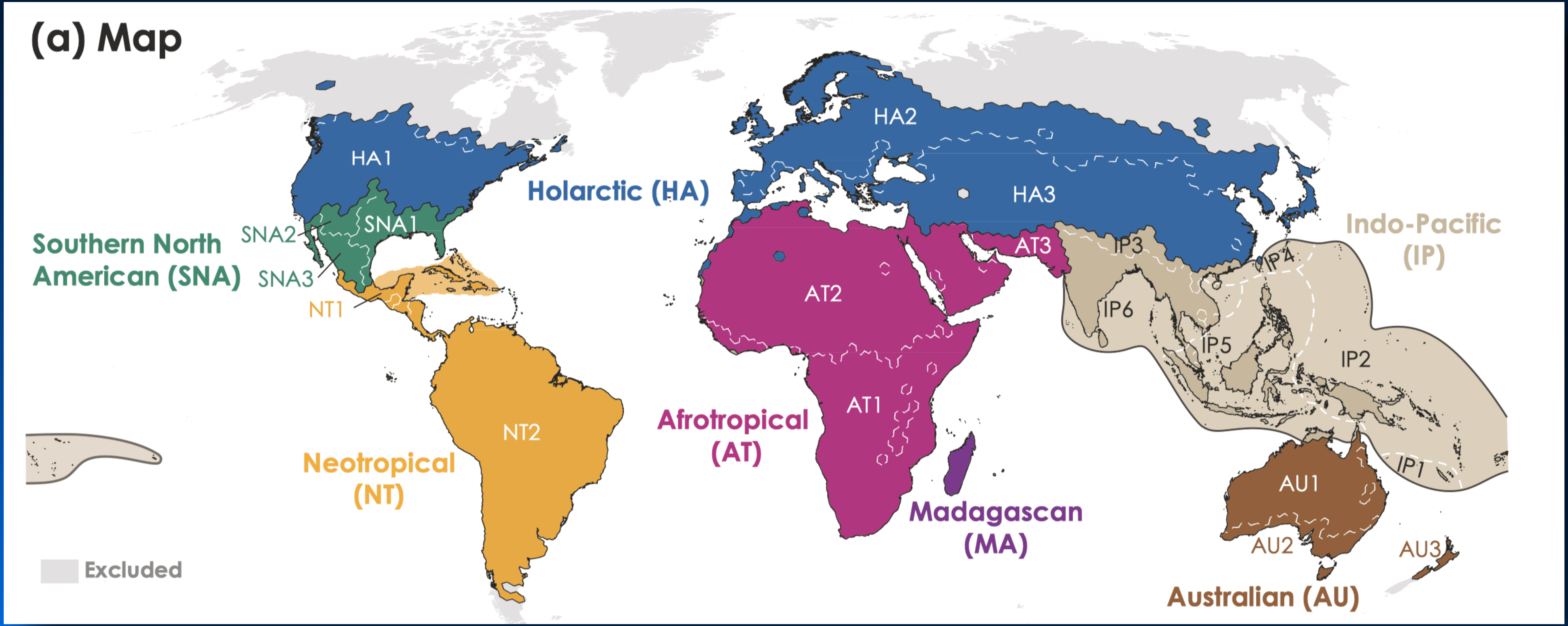

Diagram from Wang et al. (2024)

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Assessing Patterns of Biogeographic Similarity

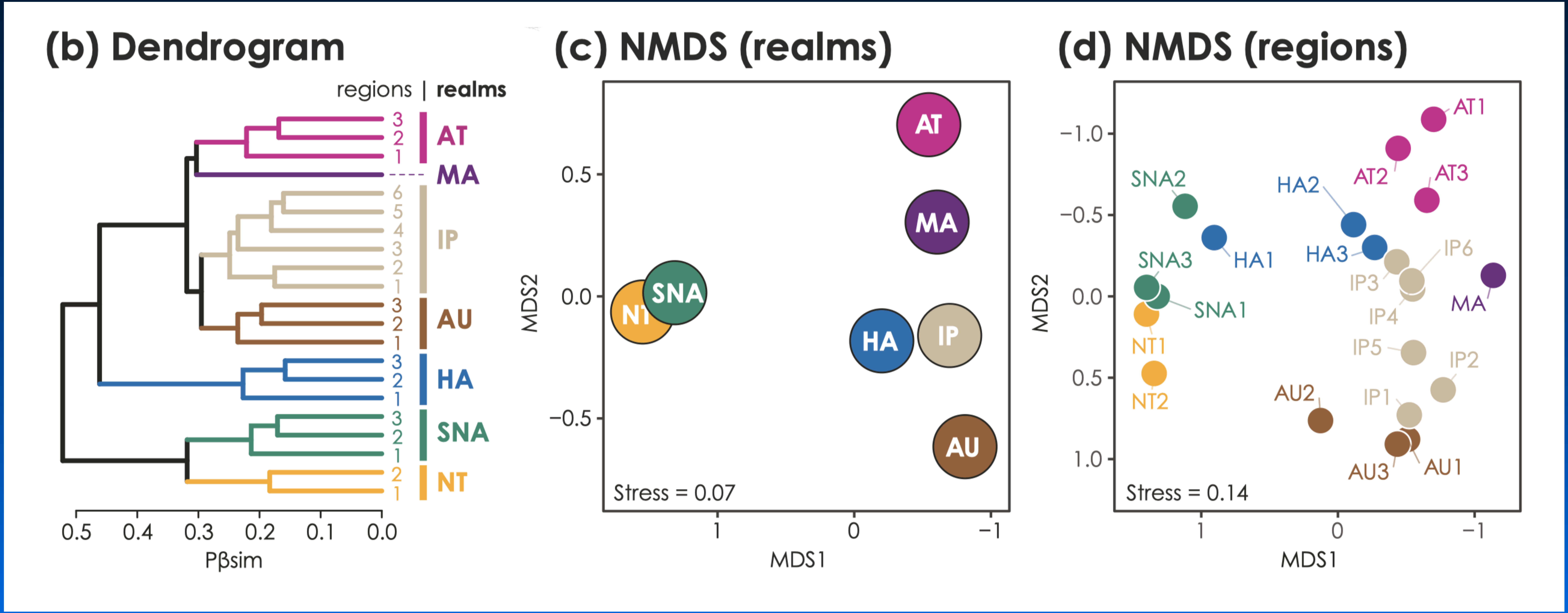

Diagram from Wang et al. (2024)

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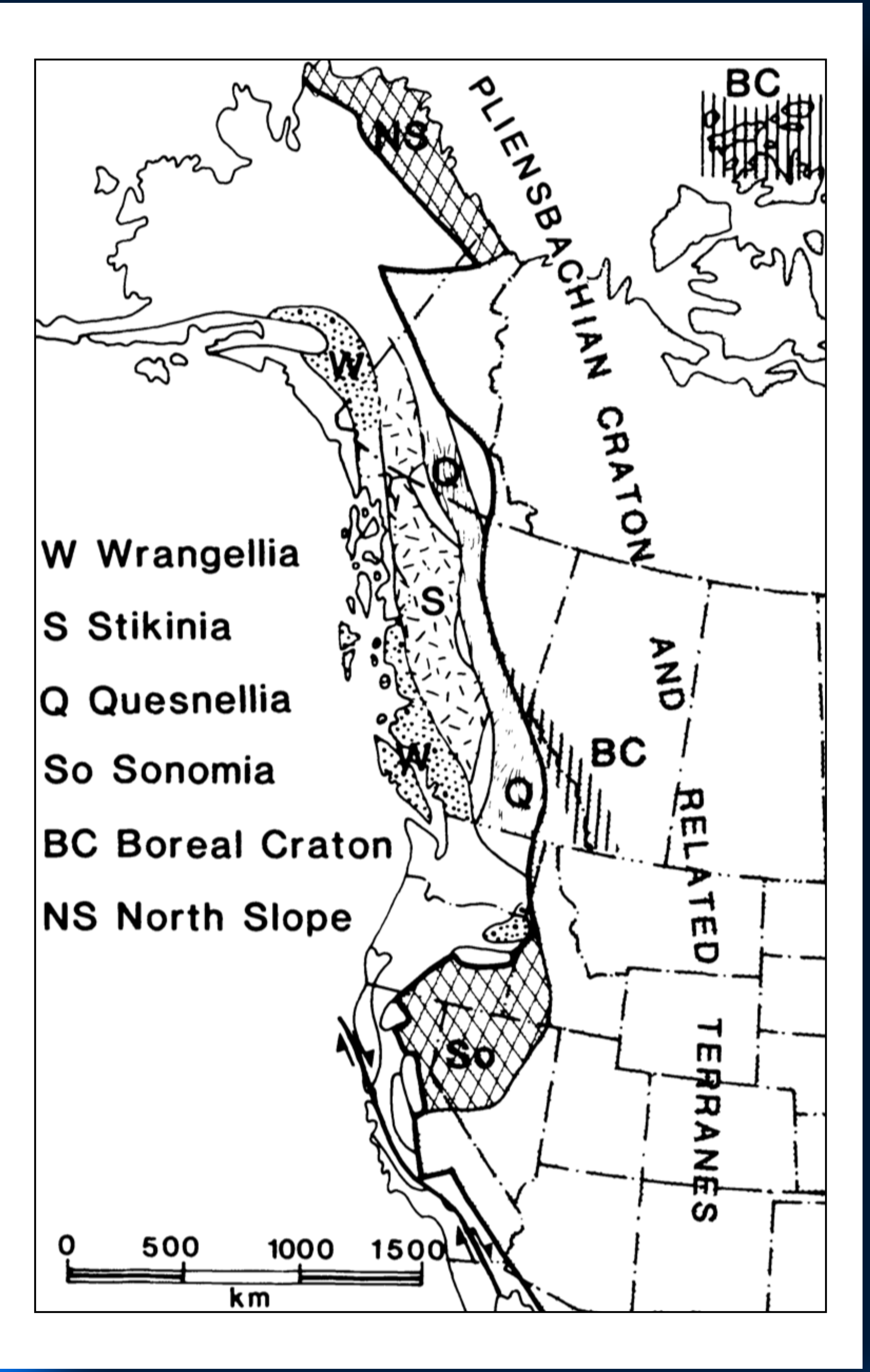
Paleobiogreography & Plate Tectonics



Amaltheus stokesi

Arieticeras algovianum

Fanninoceras sp.

Weyla alata

Aveyroniceras colubriform

Map from Smith & Tipper (1986)

Paleobiological Paleobiogeography

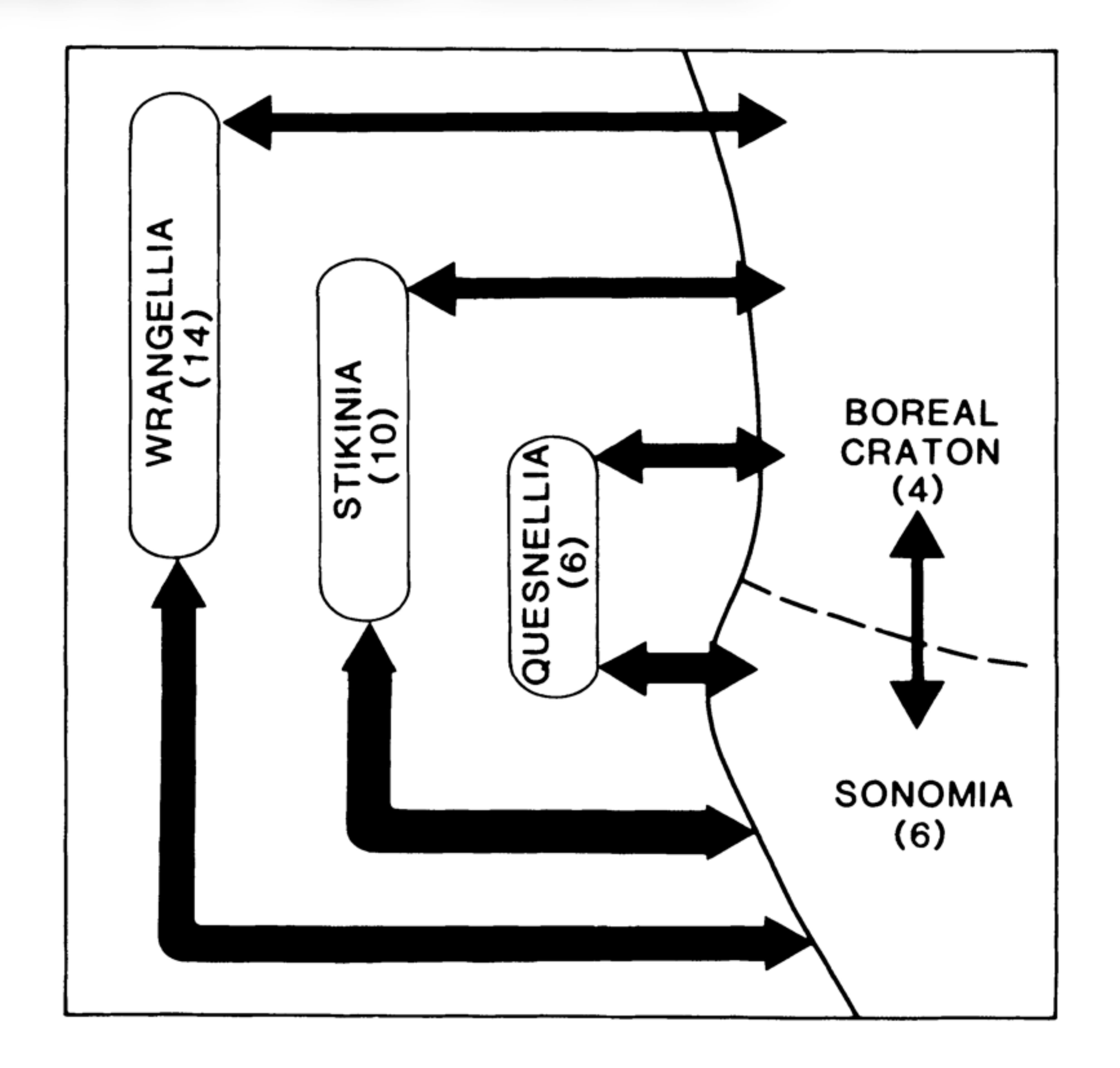
Paleobiogreography & Plate Tectonics

UPPER PLIENSBACHIAN

	WRANGELLIA	STIKINIA	QUESNELLIA	BOREAL CRATON	SONOMIA
WRANGELLIA	Σ = 14				
STIKINIA	D = 83 J = 71 S = 100	Σ = 10			
QUESNELLIA	D = 60 J = 43 S = 100	D = 63 J = 45 S = 83	Σ = 6		
BOREAL CRATON	D = 22 J = 13 S = 50	D = 29 J = 17 S = 50	D = 40 J = 25 S = 50	Σ = 4	
SONOMIA	D = 60 J = 43 S = 100	D = 75 J = 60 S = 100	D = 50 J = 33 S = 50	D = 20 J = 11 S = 17	Σ = 6

LOWER PLIENSBACHIAN

	WRANGELLIA	STIKINIA	QUESNELLIA	BOREAL CRATON	SONOMIA
WRANGELLIA	Σ = 13				
STIKINIA	D = 72 J = 56 S = 75	Σ = 12			
QUESNELLIA	D = 38 J = 23 S = 100	D = 40 J = 25 S = 100	Σ = 3		
BOREAL CRATON	D = 38 J = 23 S = 100	D = 27 J = 15 S = 67	D = 0 J = 0 S = 0	Σ = 3	
SONOMIA	D = 50 J = 33 S = 71	D = 53 J = 36 S = 71	D = 60 J = 43 S = 100	D = 0 J = 0 S = 0	Σ = 7



Data & Map from Smith & Tipper (1986)

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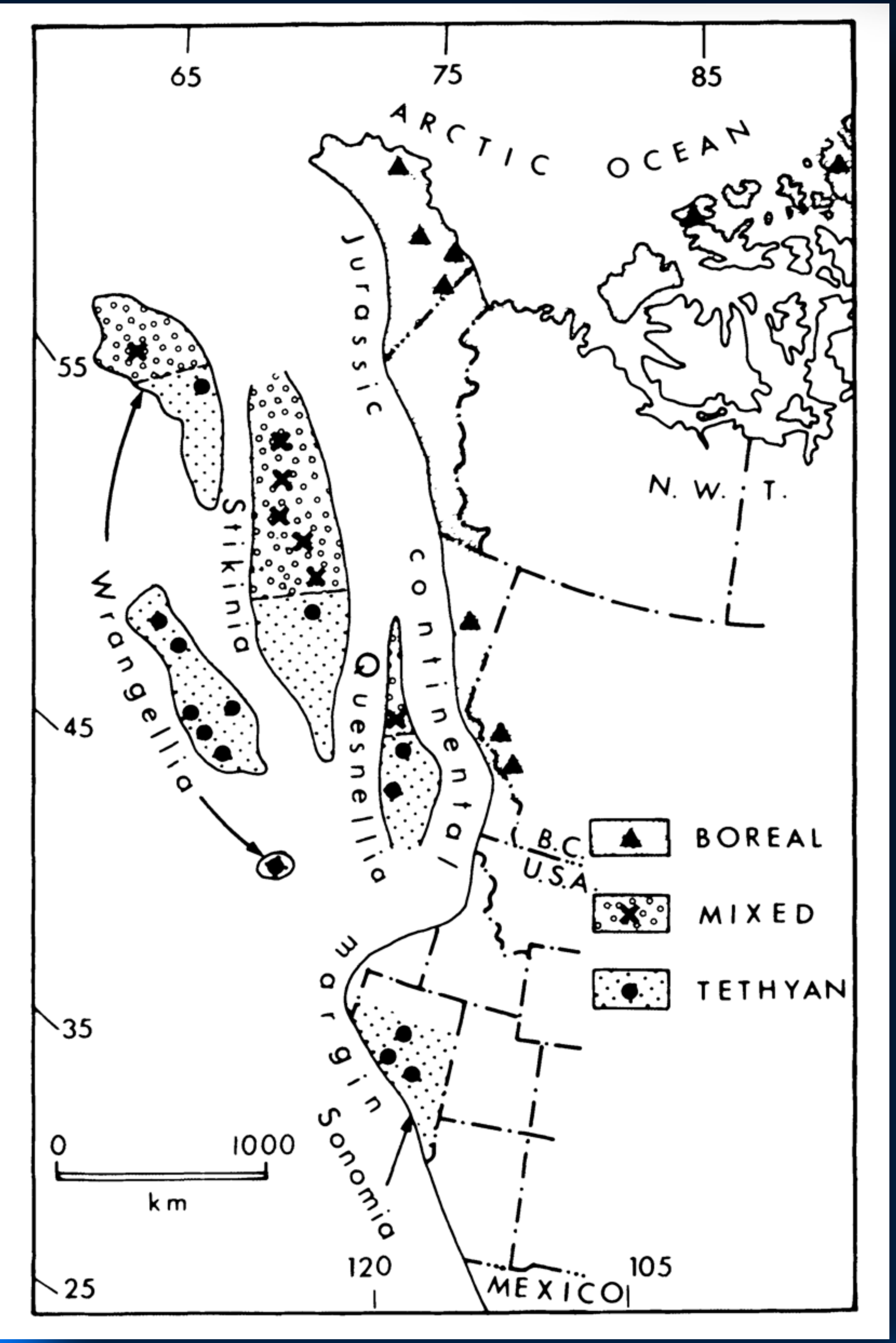
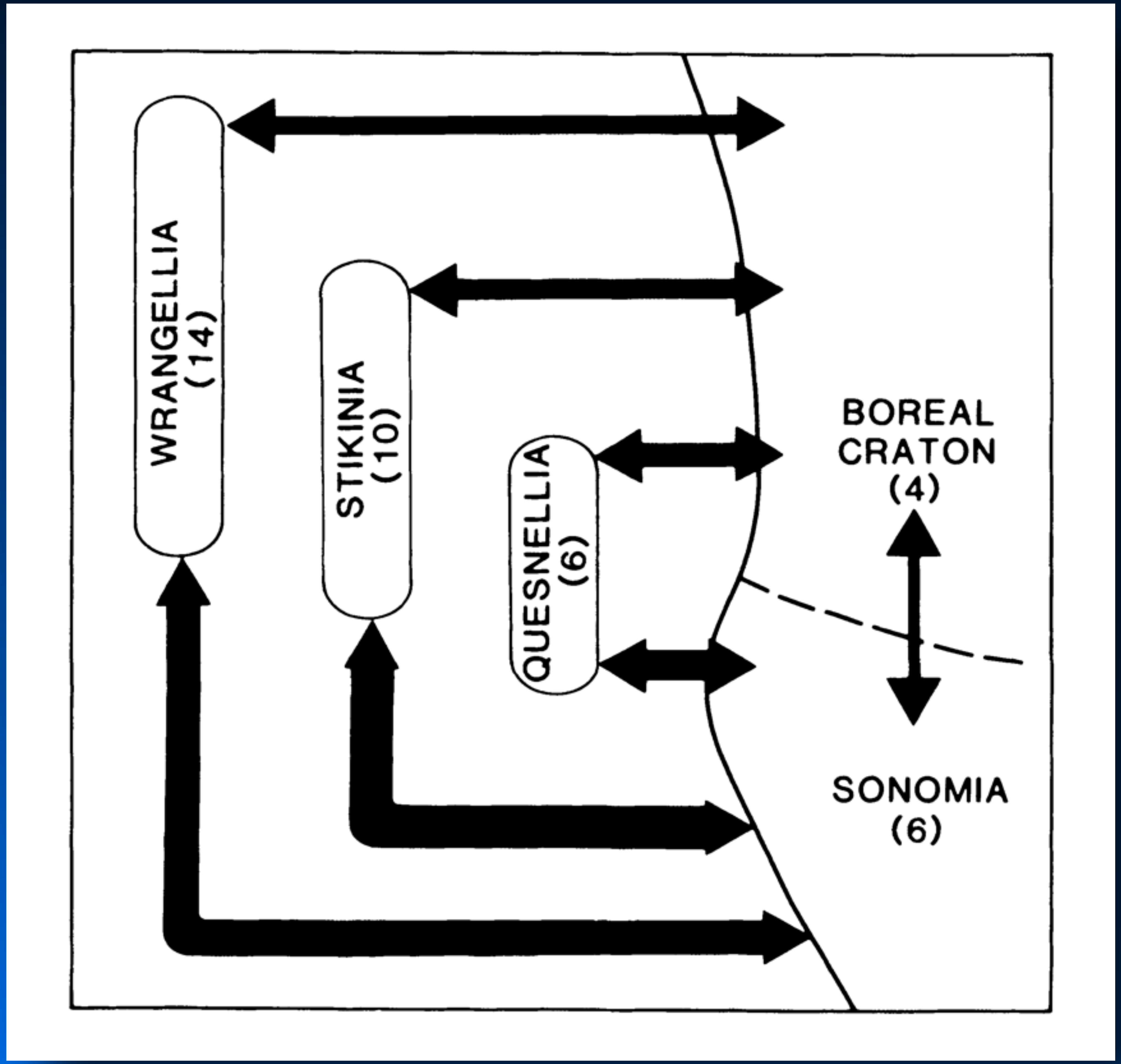
Paleobiogreography & Plate Tectonics





Data & Map from Smith & Tipper (1986)

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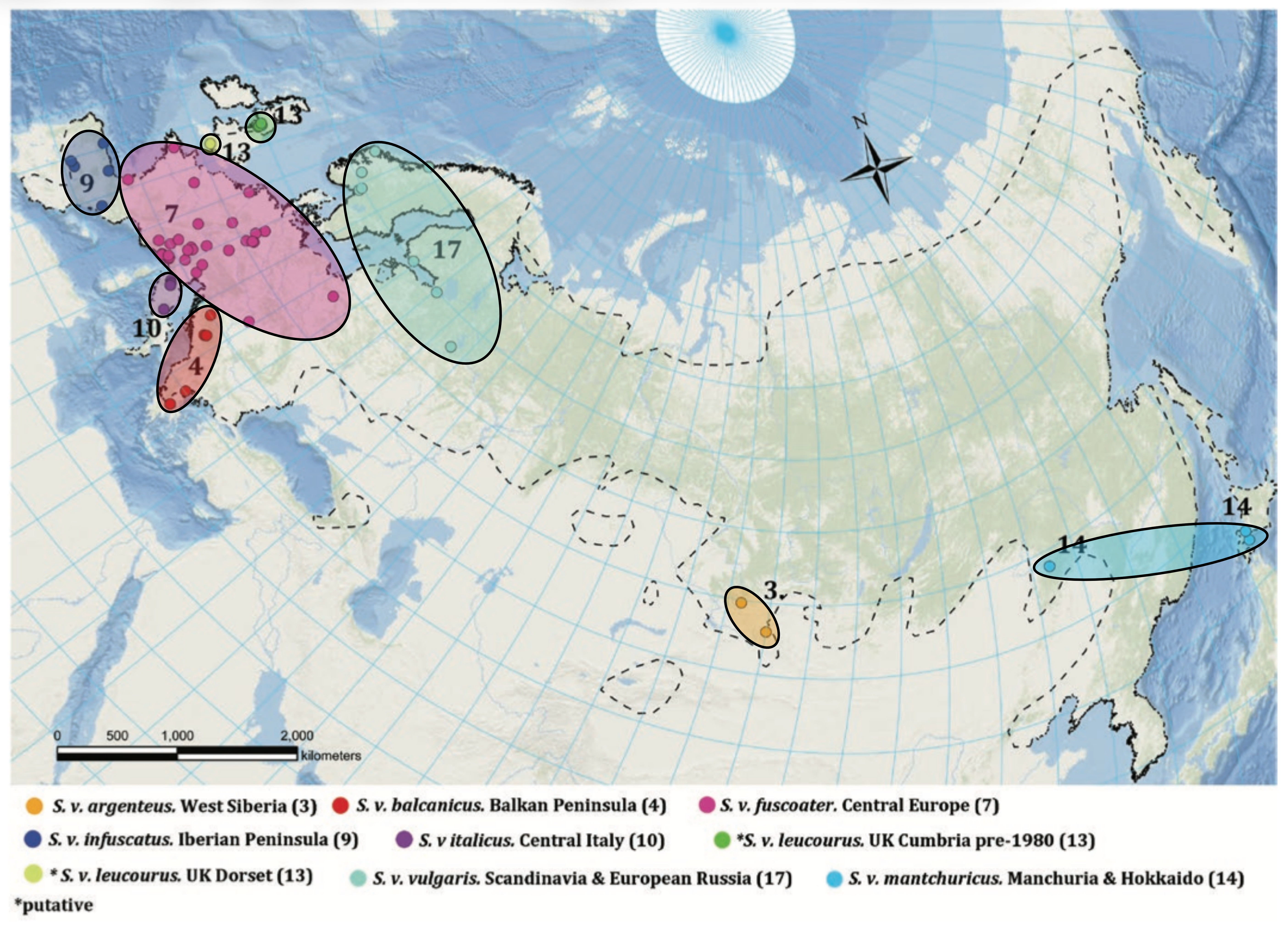
How do disjunct geographic ranges come about?



Map from Marr & MacLeod (2019)

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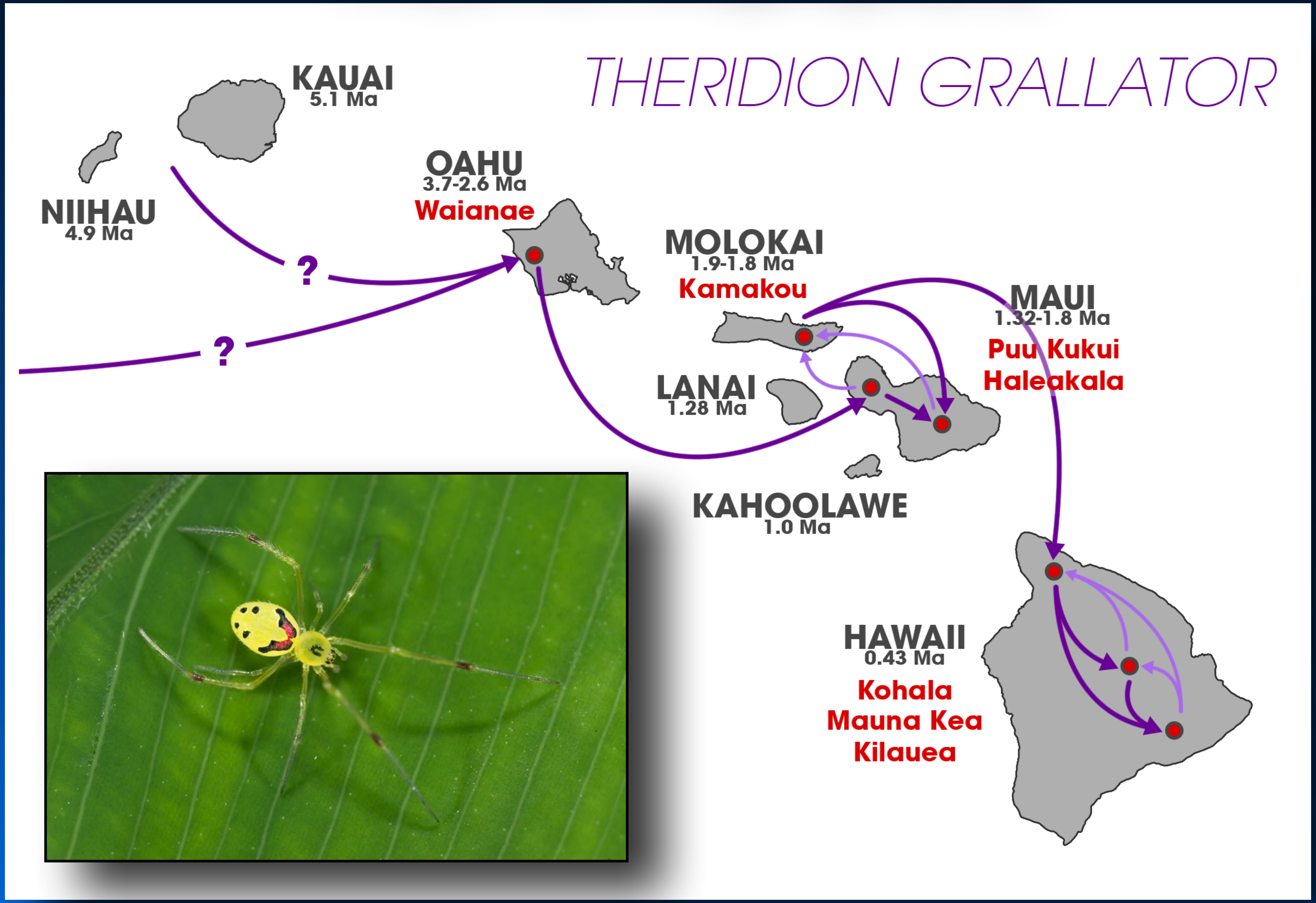
Dispersal Biogeography



Geographic dispersal occurs when a population or species surmounts a barrier to gene flow (interbreeding) that restricted its geographic range in former times.

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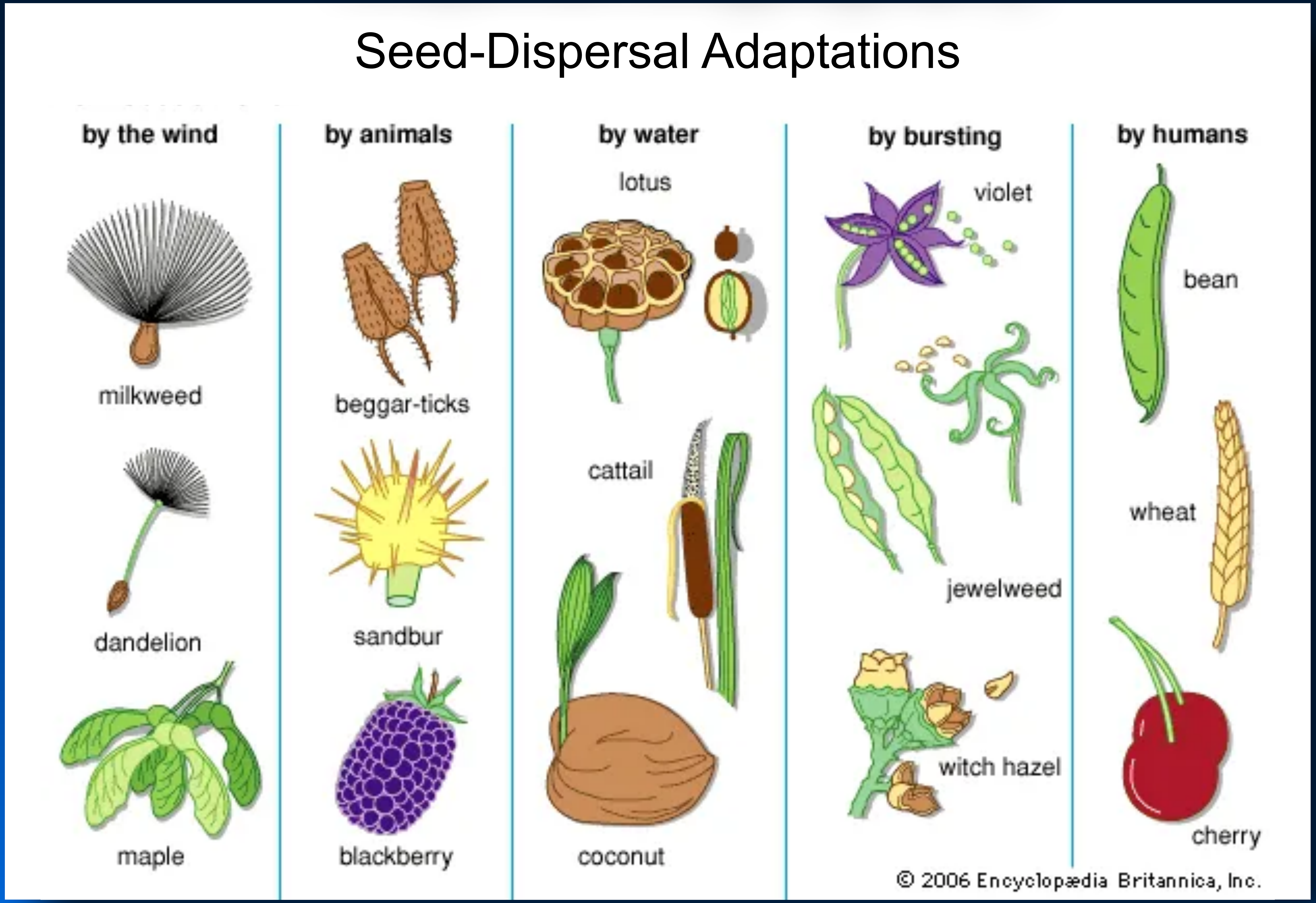
Dispersal Biogeography



Many plants depend on the dispersal of their seed, and so have evolved various morphological adaptations to take advantage of features of their local environments for this purpose.

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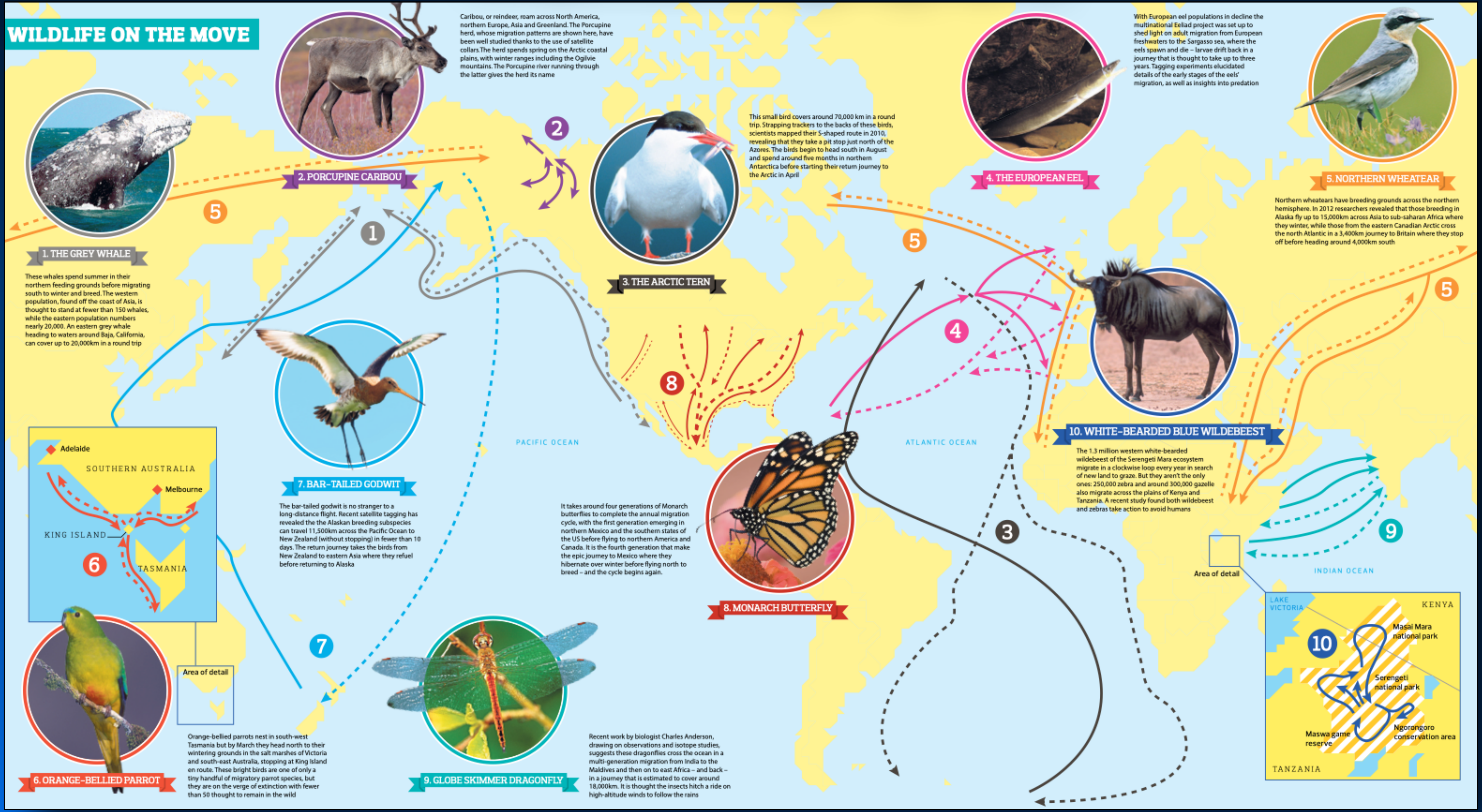
Dispersal Biogeography



Animals also exhibit a wide range of adaptations that allow them to disperse across vast distances.

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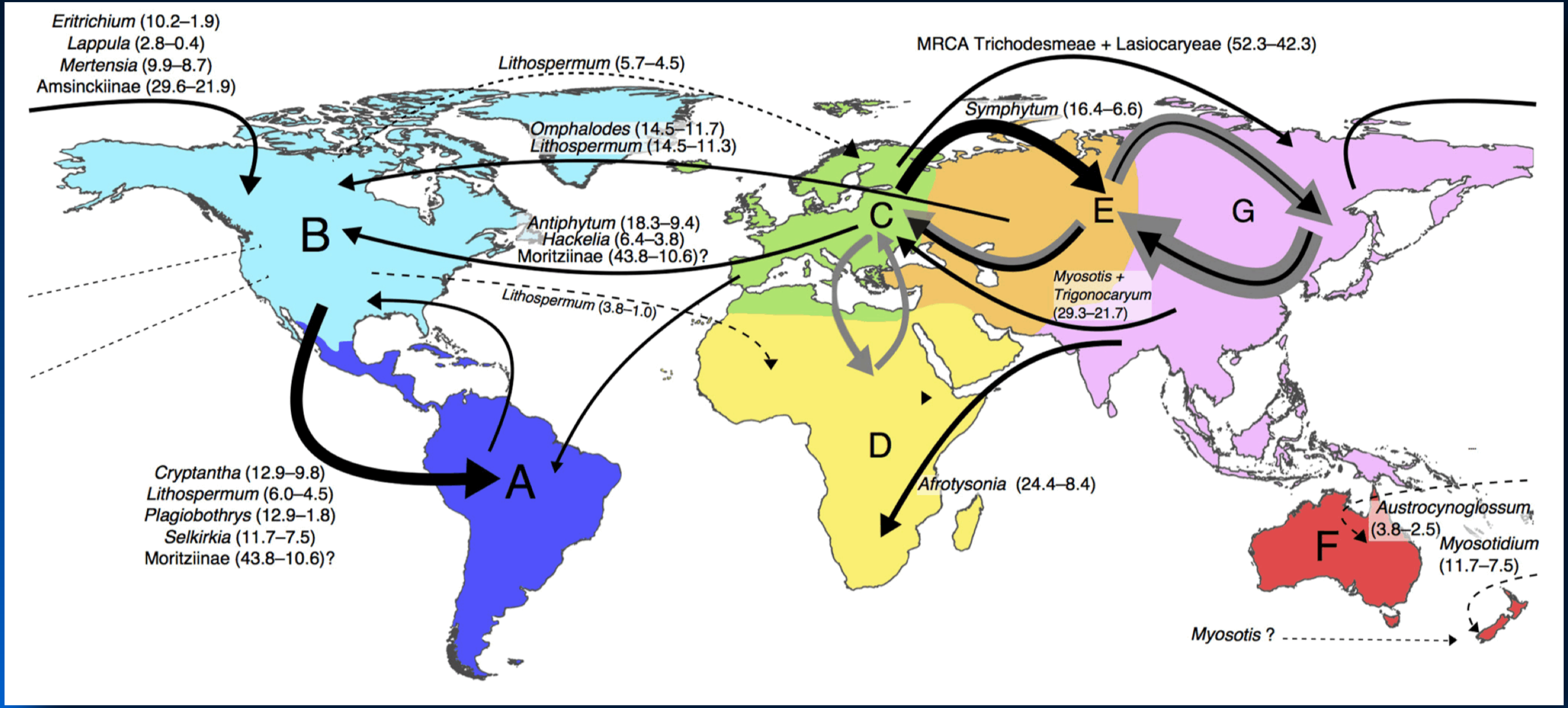
Dispersal vs Vicariance Biogeography



In the classic sweepstakes dispersal model dispersal events are independent. This means that they would (1) not always follow the same geographic track and (2) have different times associated with different dispersal-based speciation events.

Diagram from Chacón et al. (2017)

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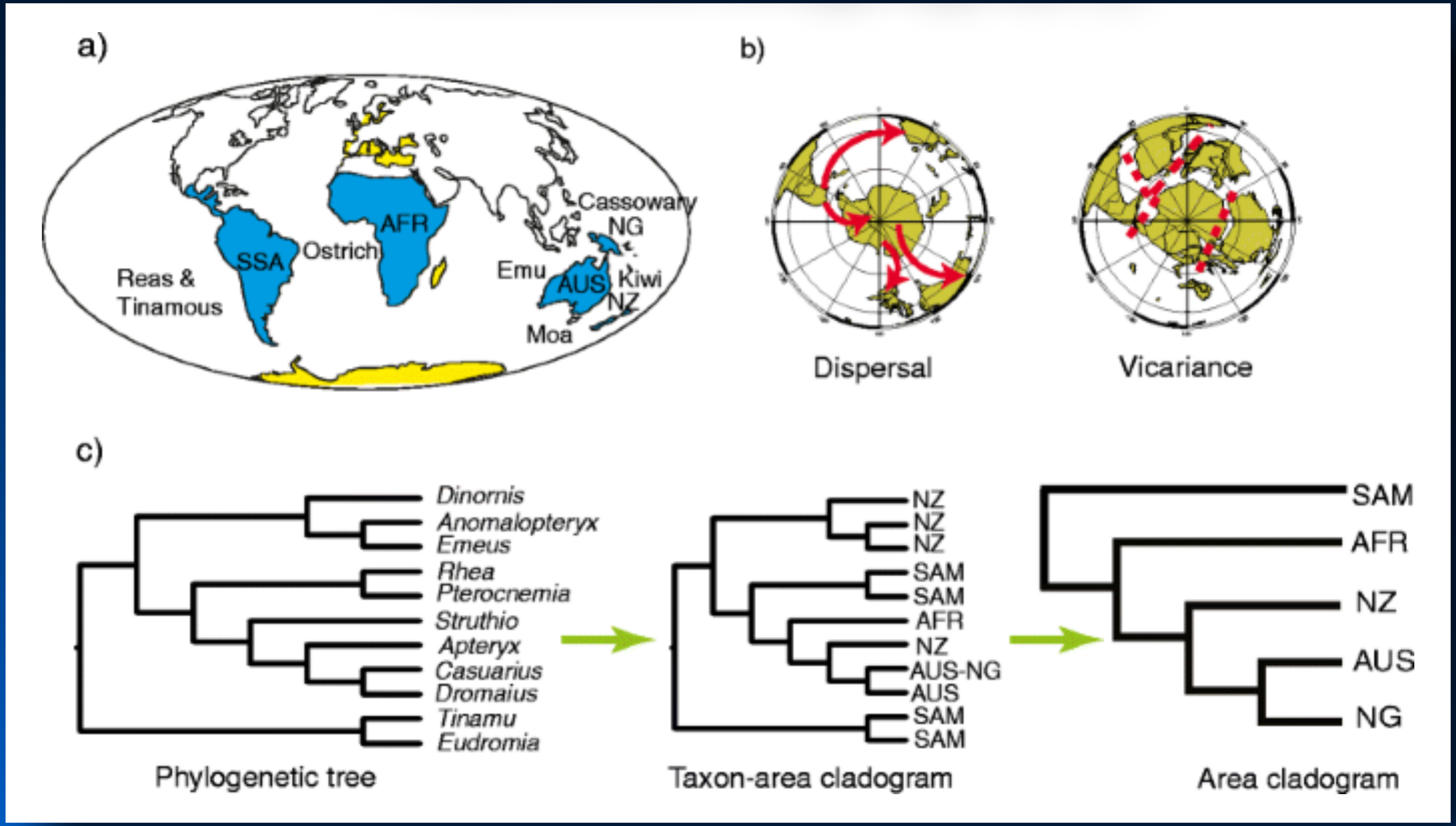
Vicariance Biogeography



In the classic vicariance model dispersal events are coordinated. This means that, among multiple lineages, they would (1) always follow the same geographic track (2) have similar times associated with different dispersal-based speciation events and (3) the ancestral species would be have been present in both old and new areas.

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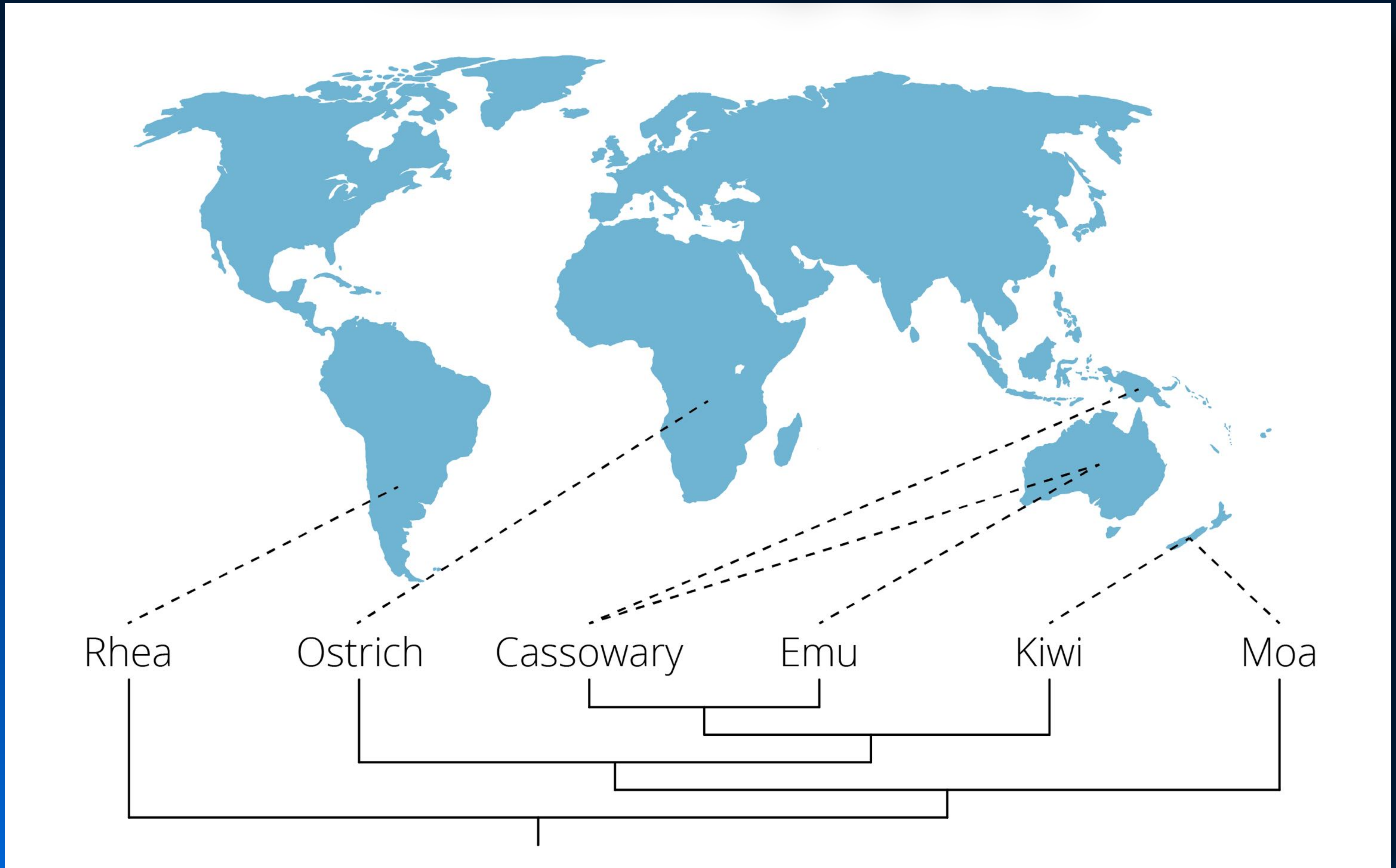
Vicariance Biogeography



A vicariance event occurs when formerly contiguous population is divided by the appearance of a barrier that restricts its gene flow/interbreeding.

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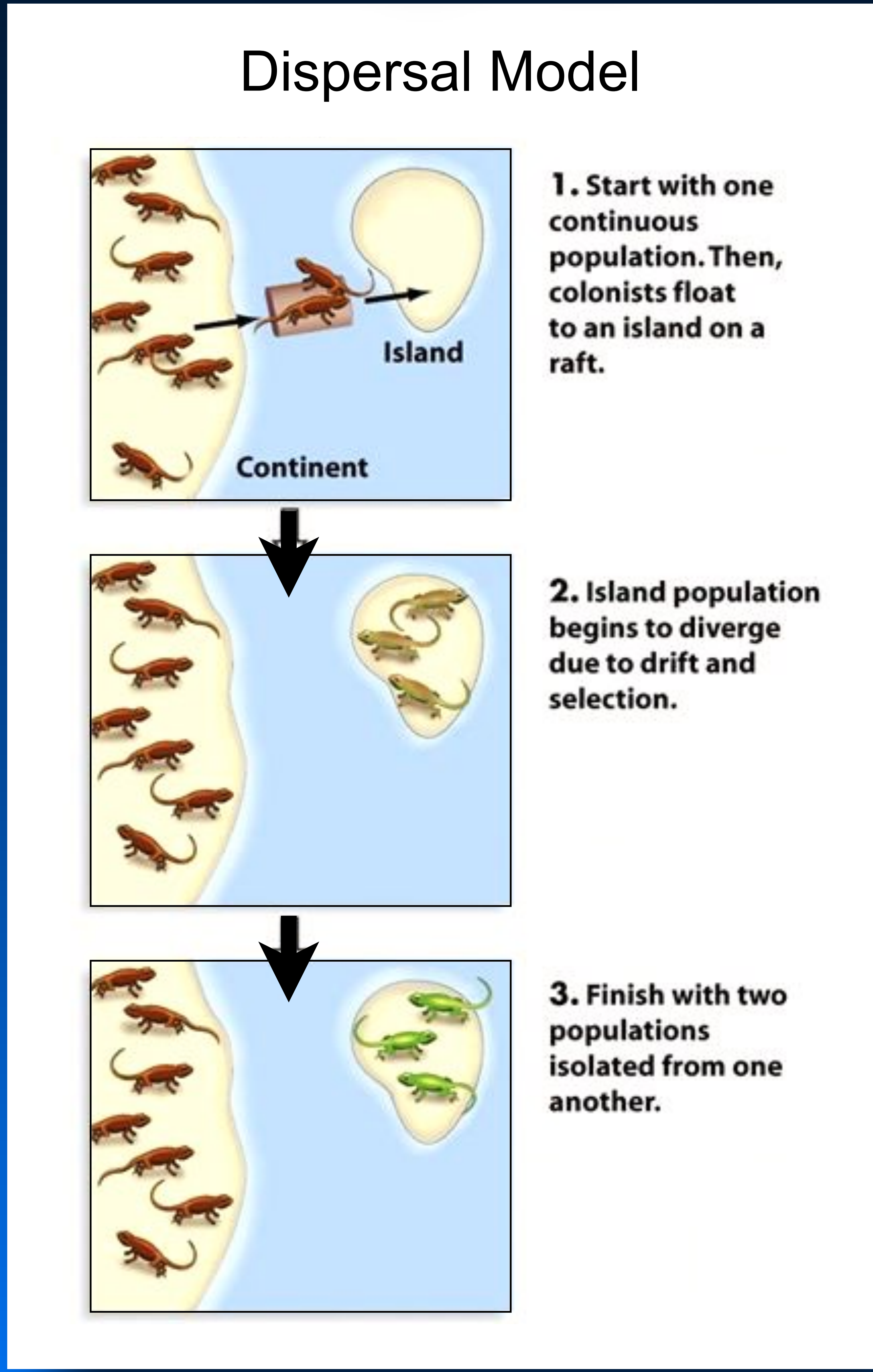
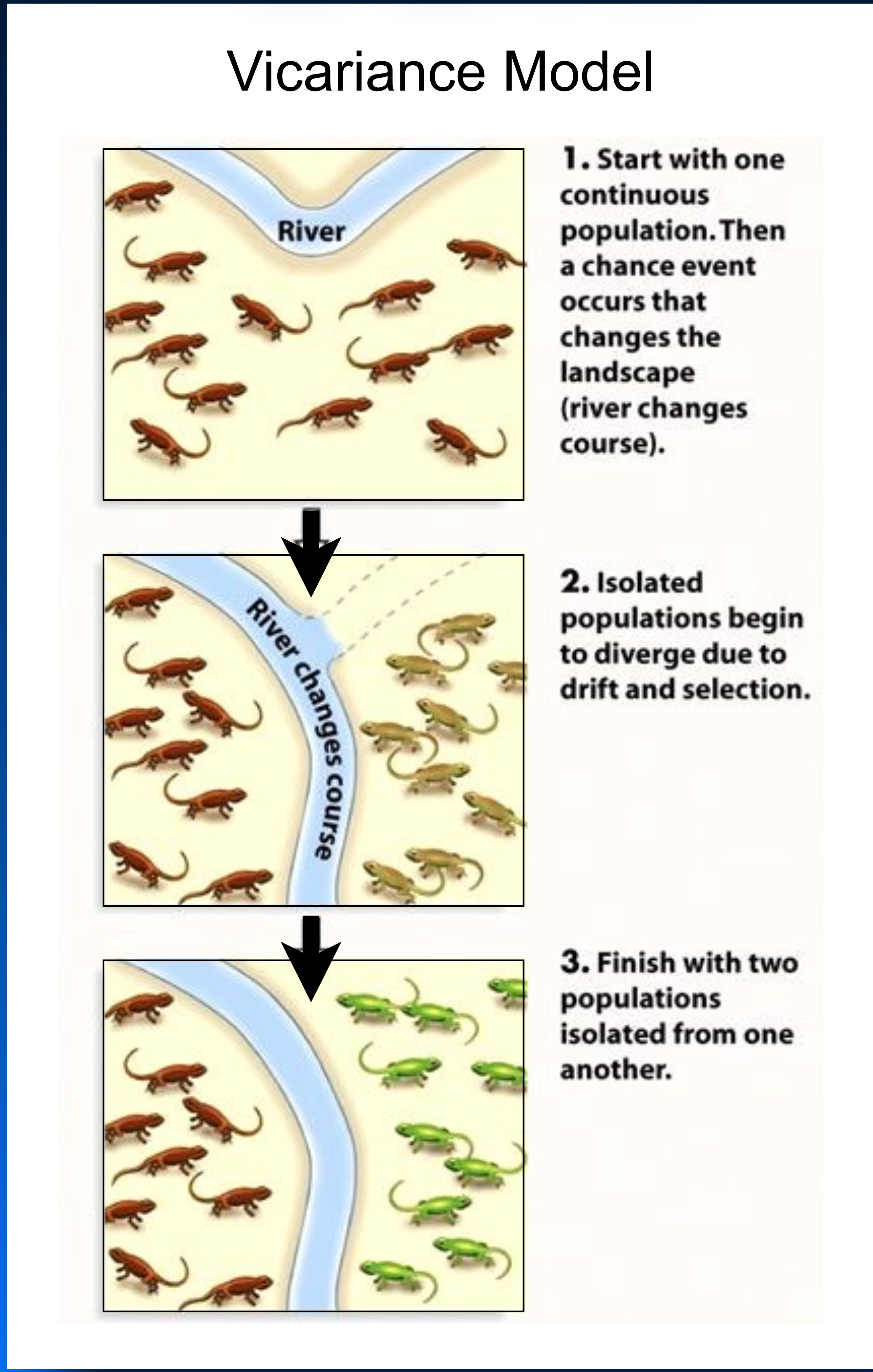
Dispersal vs Vicariance Biogeography





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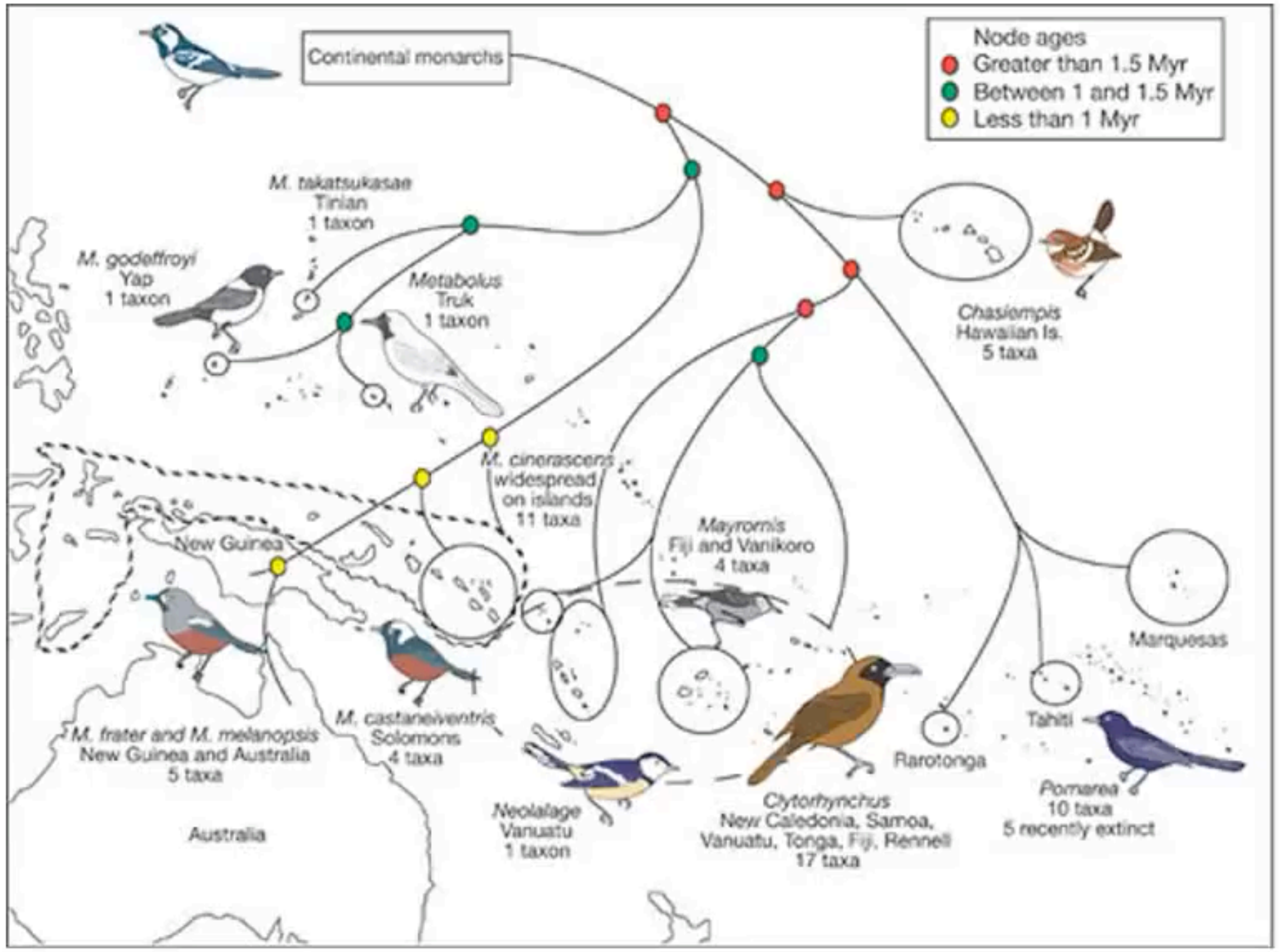
Dispersal vs Vicariance Biogeography

Paleobiogeography: Vicariance and Dispersal



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