

# Biogeography and Evolution in the Tropics

Review major biogeographic regions  
Impact of events on biodiversity patterns  
(continental drift, mountain building)

# Major biogeographic regions

Biogeography can be defined as the study of distributions of organisms as they vary from one region to another.

Major geological events in Earth's history have left their signature on the distribution of species and lineages that we see today:

- Climate change (shifting distributions of biomes)
- Separation of continents (continental drift & plate tectonics)
- Mountain building (orogeny and mountain uplift)

# Major biogeographic regions

*Vicariance* (the separation and subsequent evolution of populations) and *endemism* (species being restricted to a certain area) result from these geological events.

All 71 extant lemur species are restricted to Madagascar



# Major biogeographic regions

*Vicariance* (the separation and subsequent evolution of populations) and *endemism* (species being restricted to a certain area) result from these geological events.

These vertebrates endemic to the Galapagos Islands have ancestry traced to animals living in South America





# Major biogeographic regions

Each region is distinct because it has various groups of endemic plants and animals



# Major biogeographic regions

Alfred Russel Wallace studied the Malay Archipelago (today largely within the country of Indonesia) – known among biogeographers as “Wallacea”

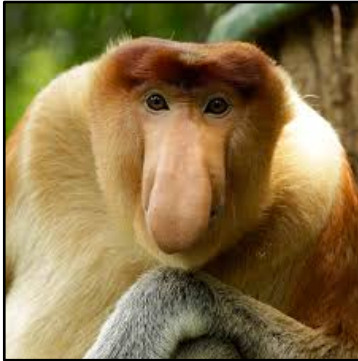
By comparing species across islands, he surmised that the archipelago is made up of two biogeographic realms (termed *Oriental* and *Australian* provinces)



# Major biogeographic regions

Animals found on either side of Wallace's Line

## Asia



Proboscis  
monkey



Flying  
lizard



Bornean  
bristlehead

## Australia



Yellow-  
crested  
Cockatoo



Tree  
kangaroo



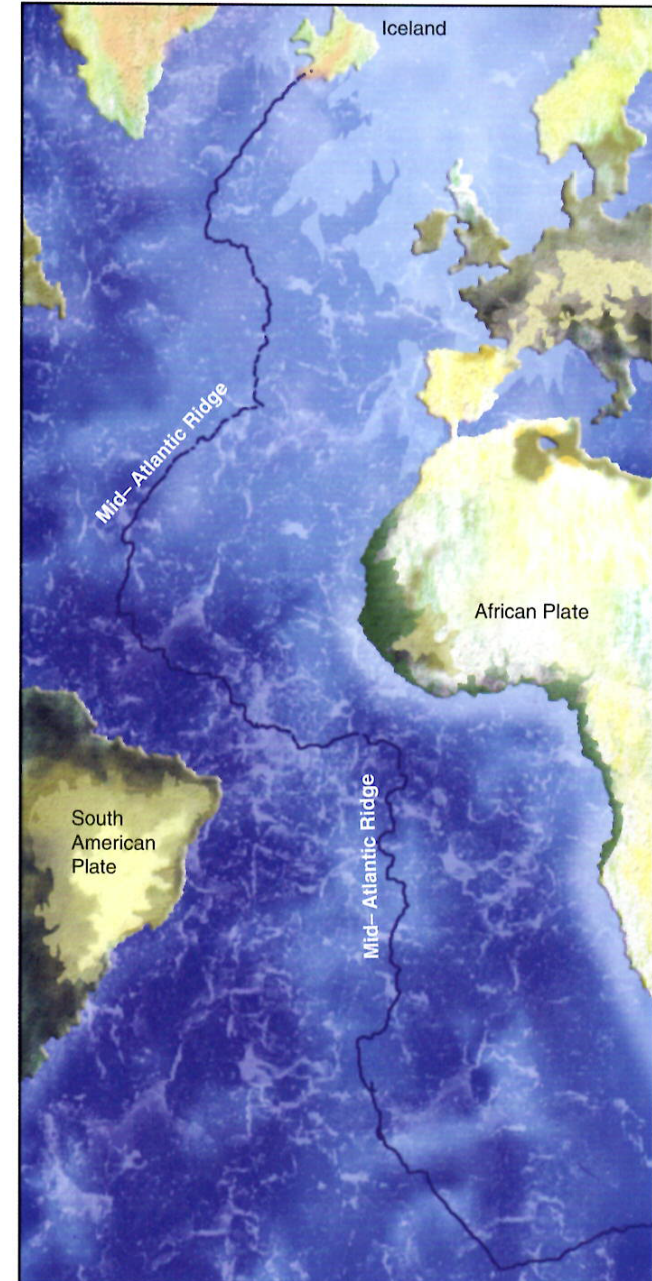
Spotted  
cuscus





# Plate Tectonics

Humboldt (in the 1800's) was the first to note the complementarity of the South American -African coastlines, suggesting that the continents could have been joined at one time.

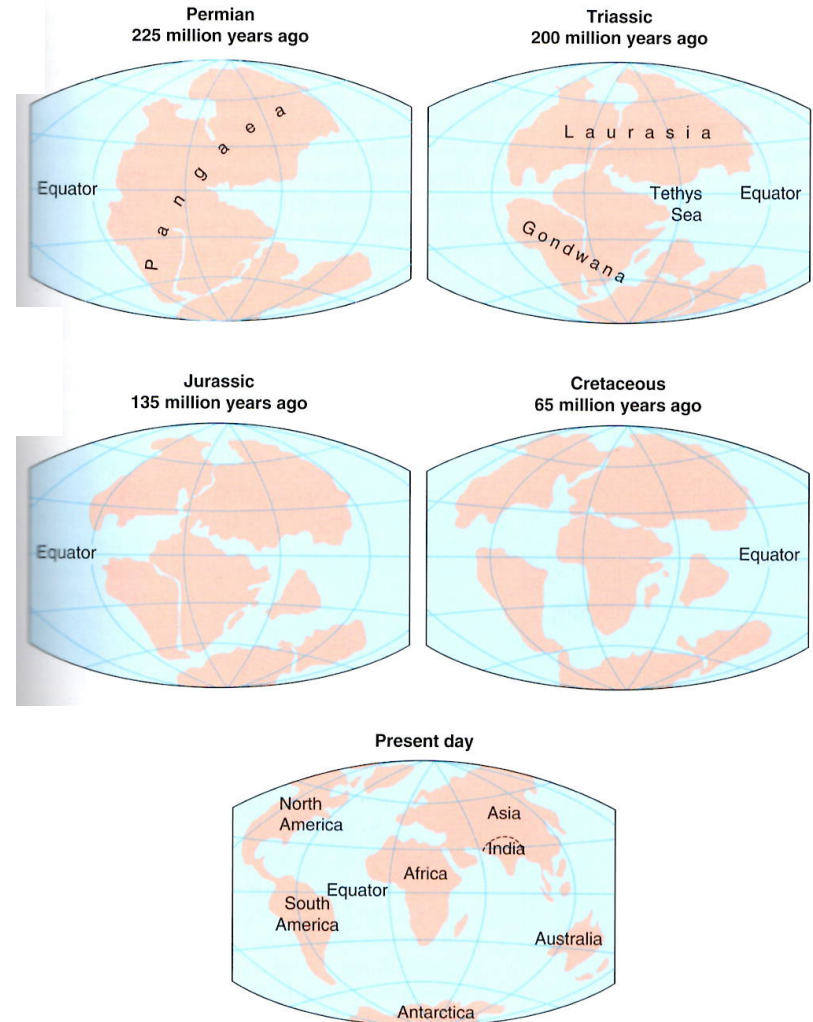




# Plate Tectonics

Alfred Wegner proposed the theory that continents moved relative to one another in 1912, which was still viewed as preposterous.

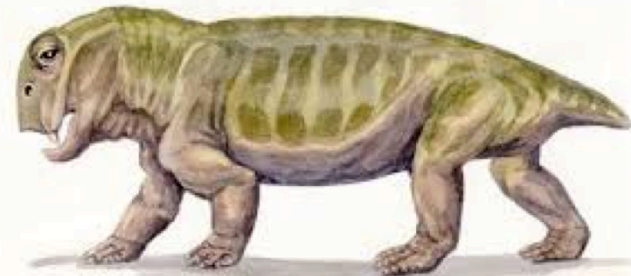
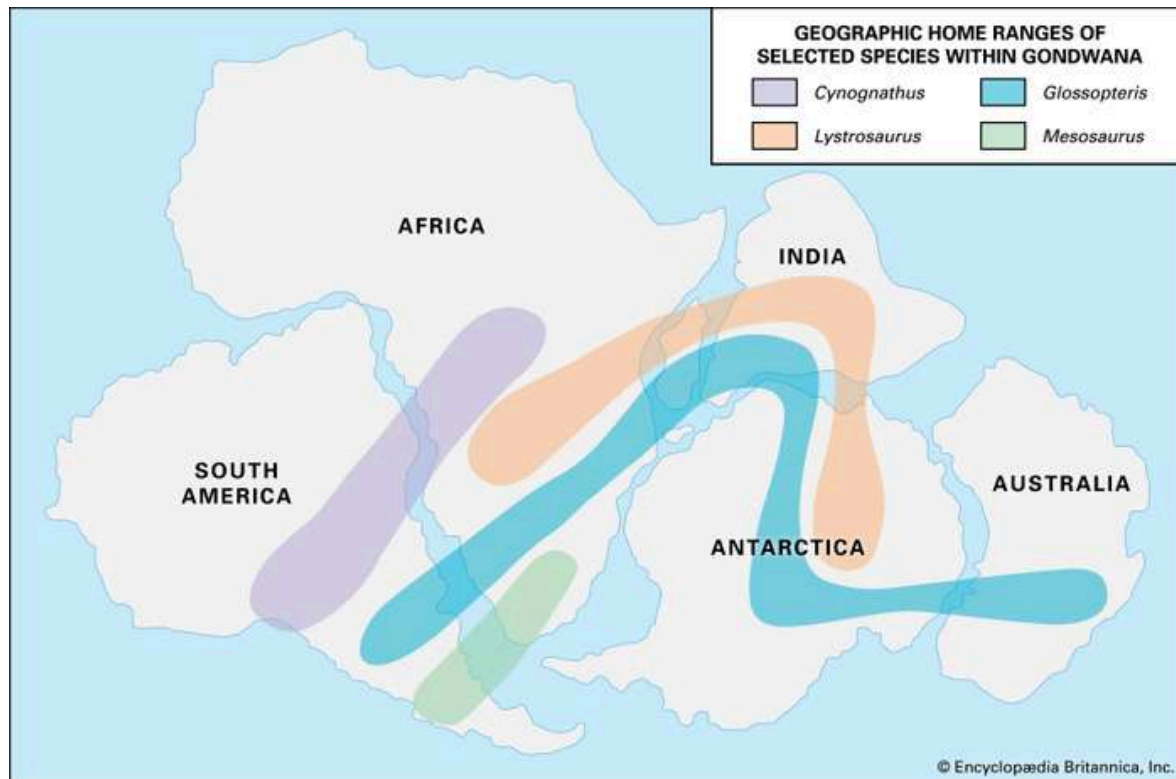
Evidence for movement of tectonic plates was slow to surface and not formally accepted until ~1950.





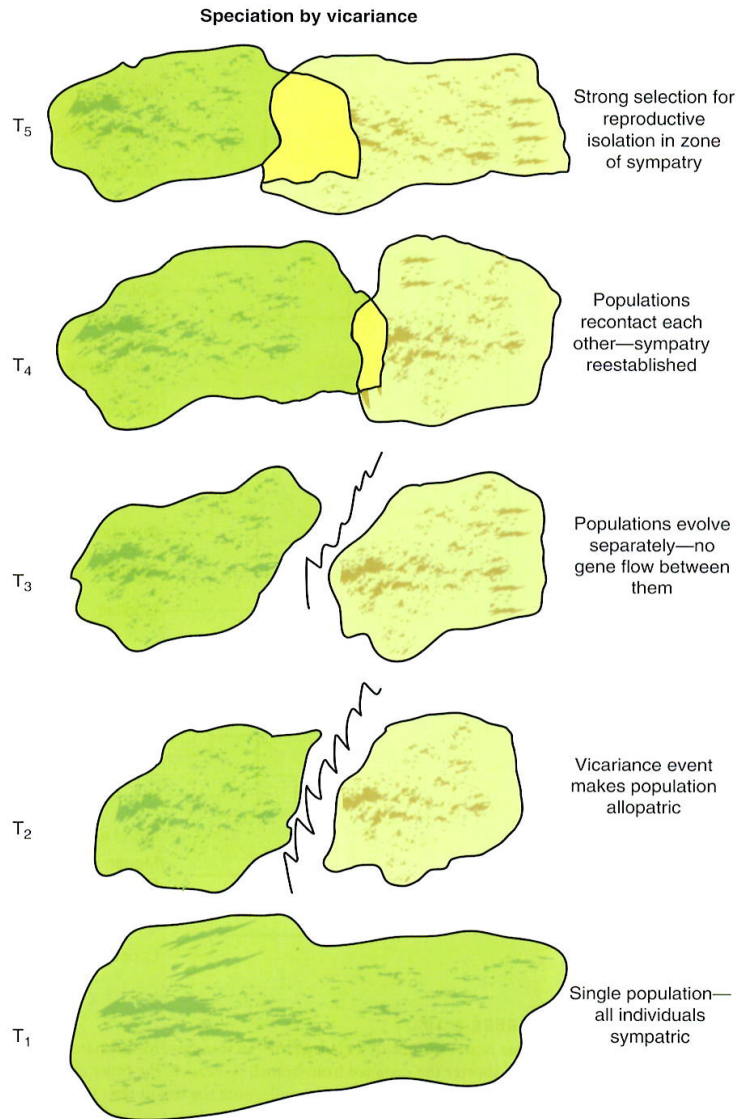
# Plate Tectonics

Meanwhile biogeographers struggled to explain disjunct distributions of related taxa...



*Lystrosaurus* with its fossils found on largely separated continents

# Speciation



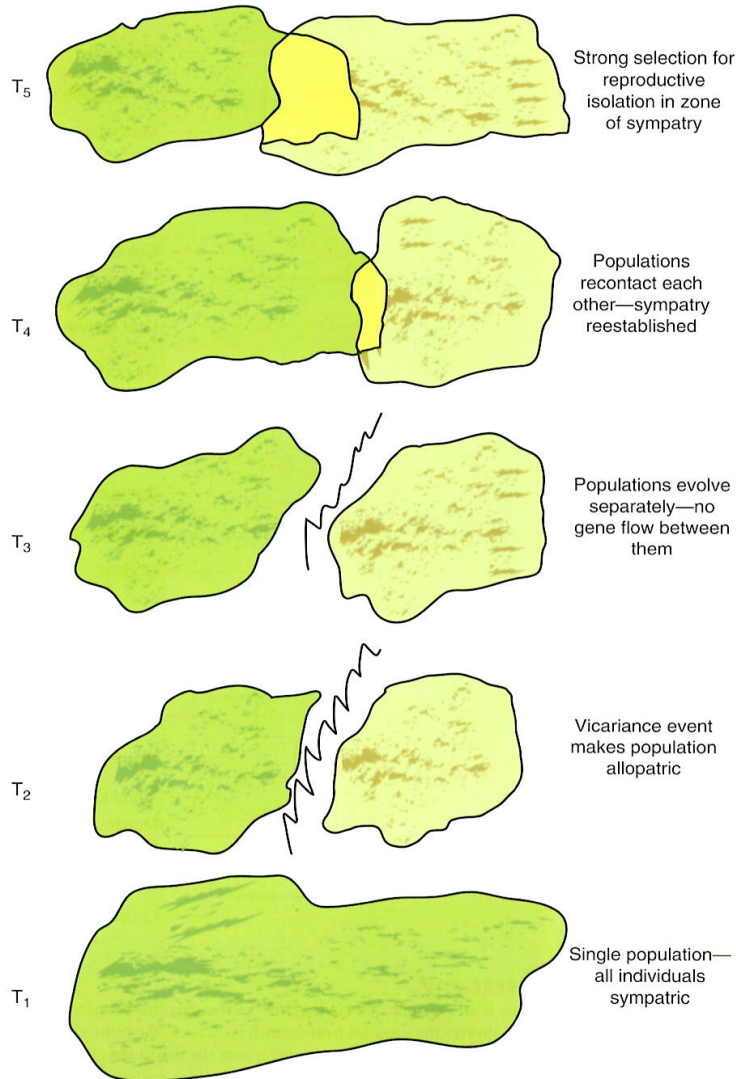
One of the most popular models for geographic speciation is divergence in allopatry

*Vicariance*: the occurrence of a physical barrier that isolates populations and halts gene flow

Speciation can occur in other geographic arrangements (e.g., divergence with gene flow)

# Speciation

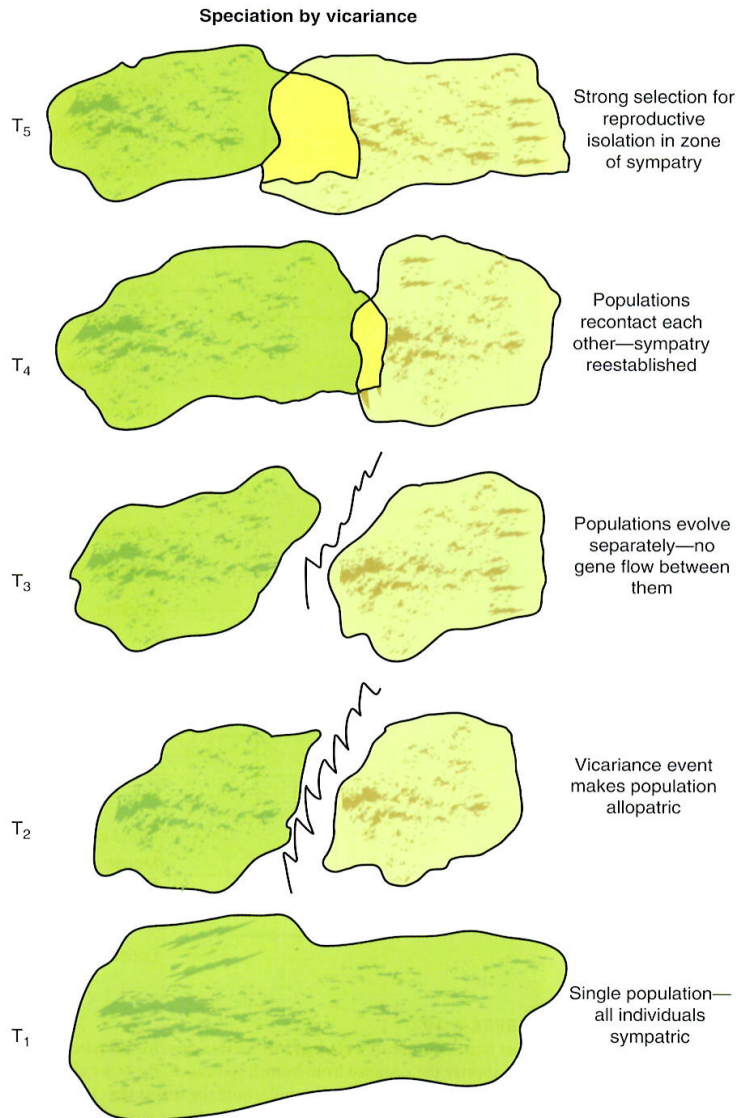
## Speciation by vicariance



**Biological Species Concept** – the most widely used definition of a species – defines species as populations of actually or potentially interbreeding organisms.

Widely accepted, and a theoretically strong definition, but often difficult to apply in the field.

# Speciation

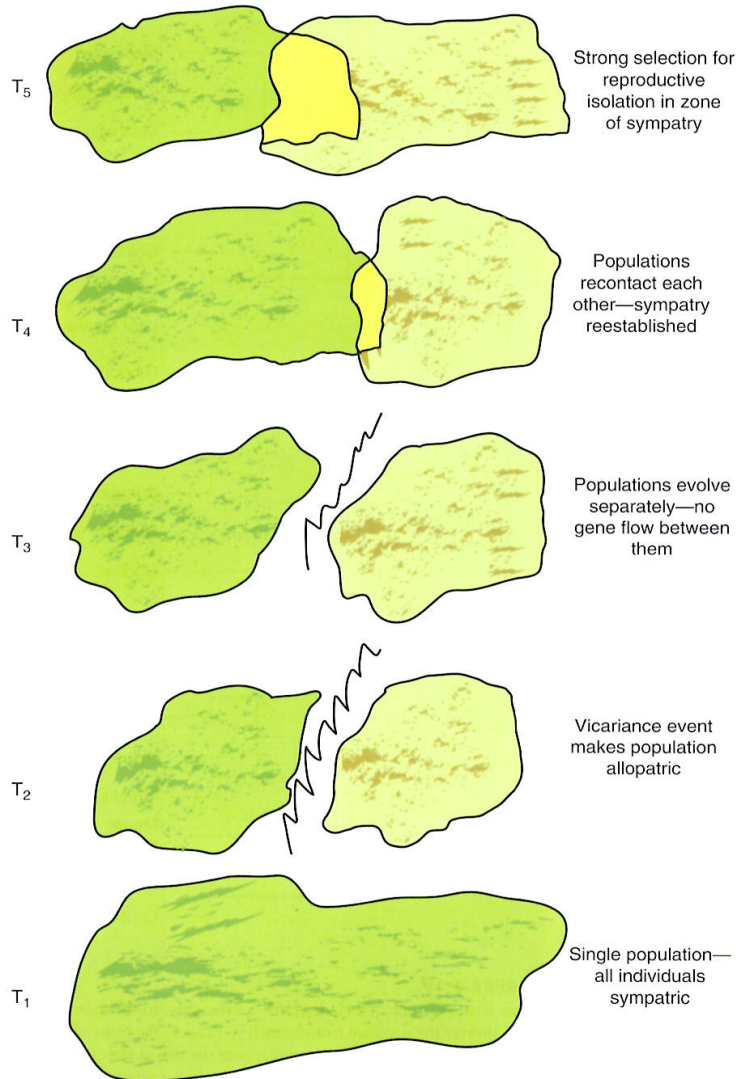


**Phylogenetic Species Concept** –  
gaining support among systematists  
– designation of species separates  
populations on the basis of recently  
derived genetic characteristics that  
are no longer shared.

Differences can be based on  
anatomical characters or molecular  
sequences

# Speciation

## Speciation by vicariance



**Phylogenetic Species Concept –**  
Focuses on ‘nodes’ when two populations diverged

Molecular distance can be measured for known species and used as a yardstick

Can be applied to subspecies, which are genetically distinct but not necessarily reproductively isolated, or occur in allopatry



# Speciation: An example with Cichlids

Cichlids are a diverse (~3000 species) group of tropical fish, most of which are found in East Africa in three lakes across the Great Rift Valley:

Lake Victoria >400 species

Lake Tanganyika 200 species

Lake Malawi 300-500 species

Various forces have contributed to this radiation, acting over a 'short' time frame



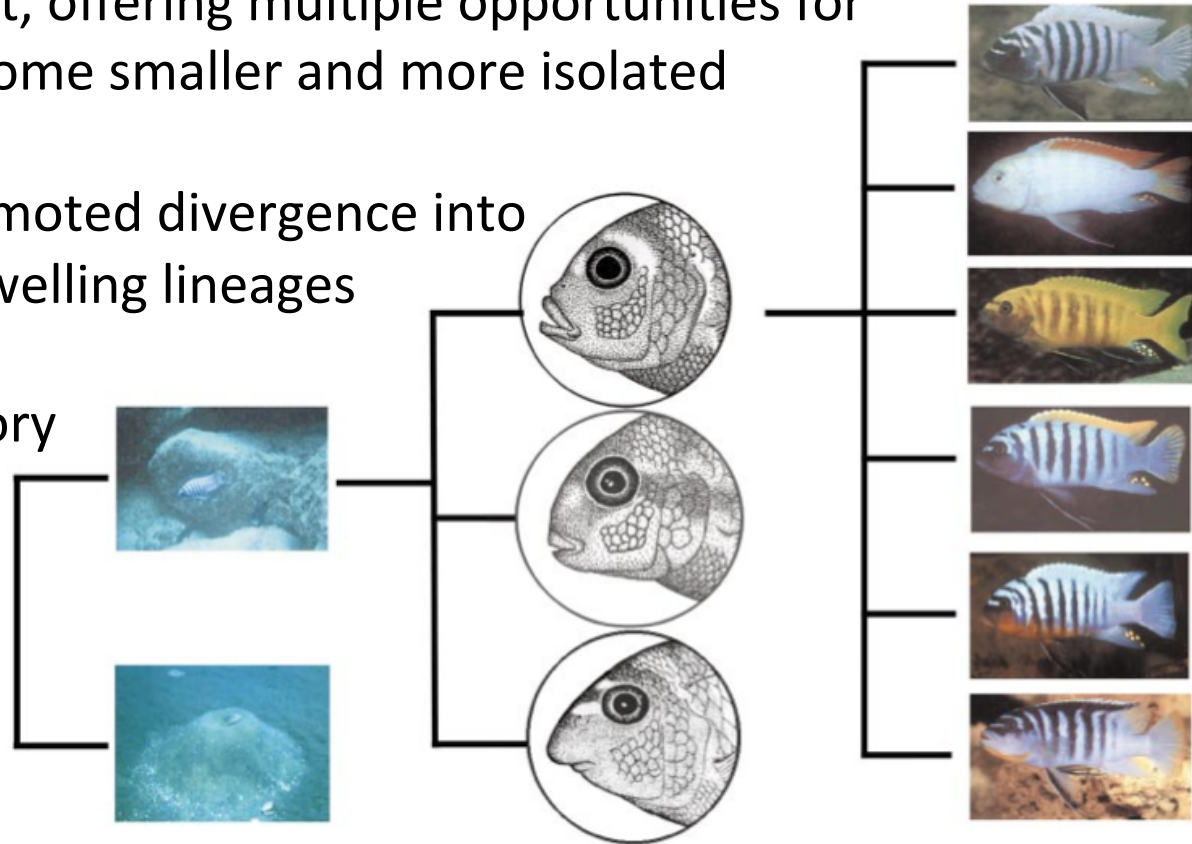
# Speciation: An example with Cichlids

Lake Malawi was invaded by a riverine generalist ~700 000 years ago

African lakes have experienced periods of extreme dryness followed by replenishment, offering multiple opportunities for cichlid populations to become smaller and more isolated

Habitat specialization promoted divergence into sand-dwelling and rock-dwelling lineages

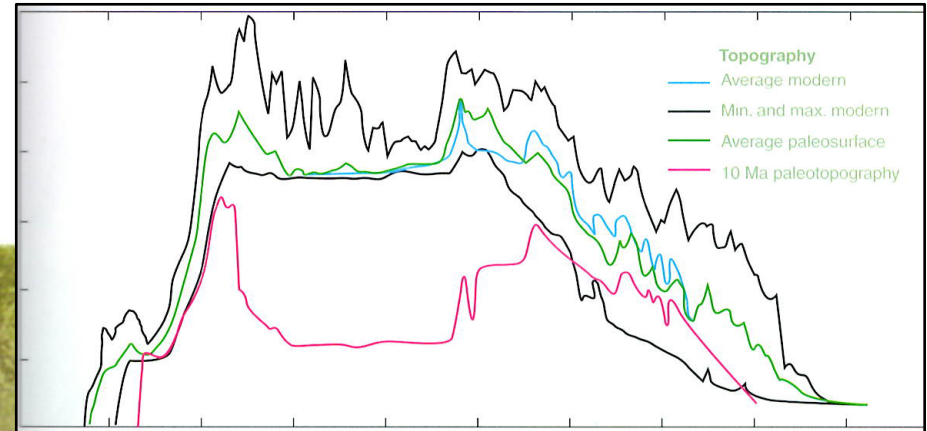
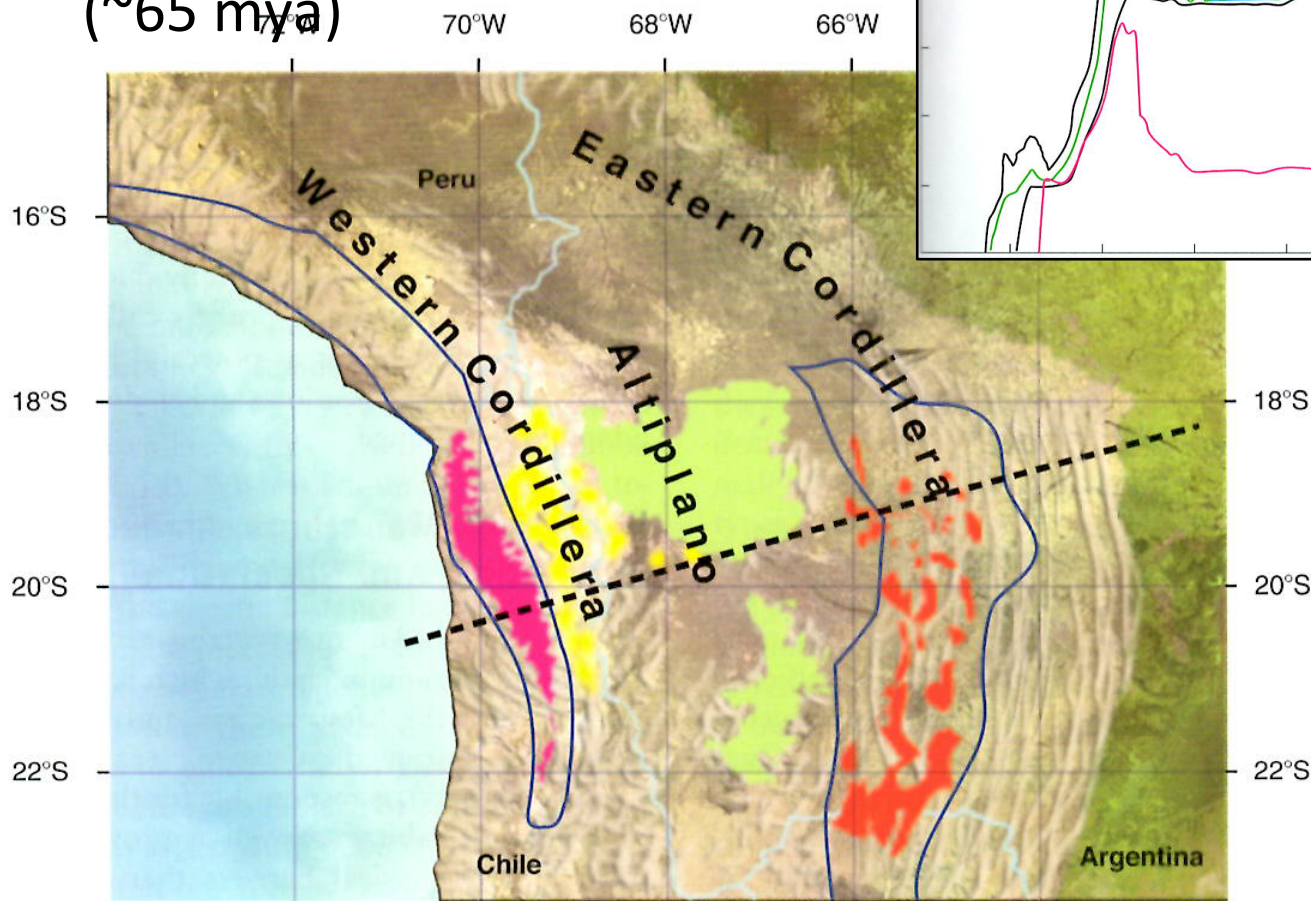
Further selection on sensory systems and *opsin* genes has promoted speciation as a function of depth (without vicariance)



(from Danley & Kocher 2001)

# Andean/Amazonia Biogeography

Geological activity and Andean uplift during the Cenozoic era  
(~65 mya)

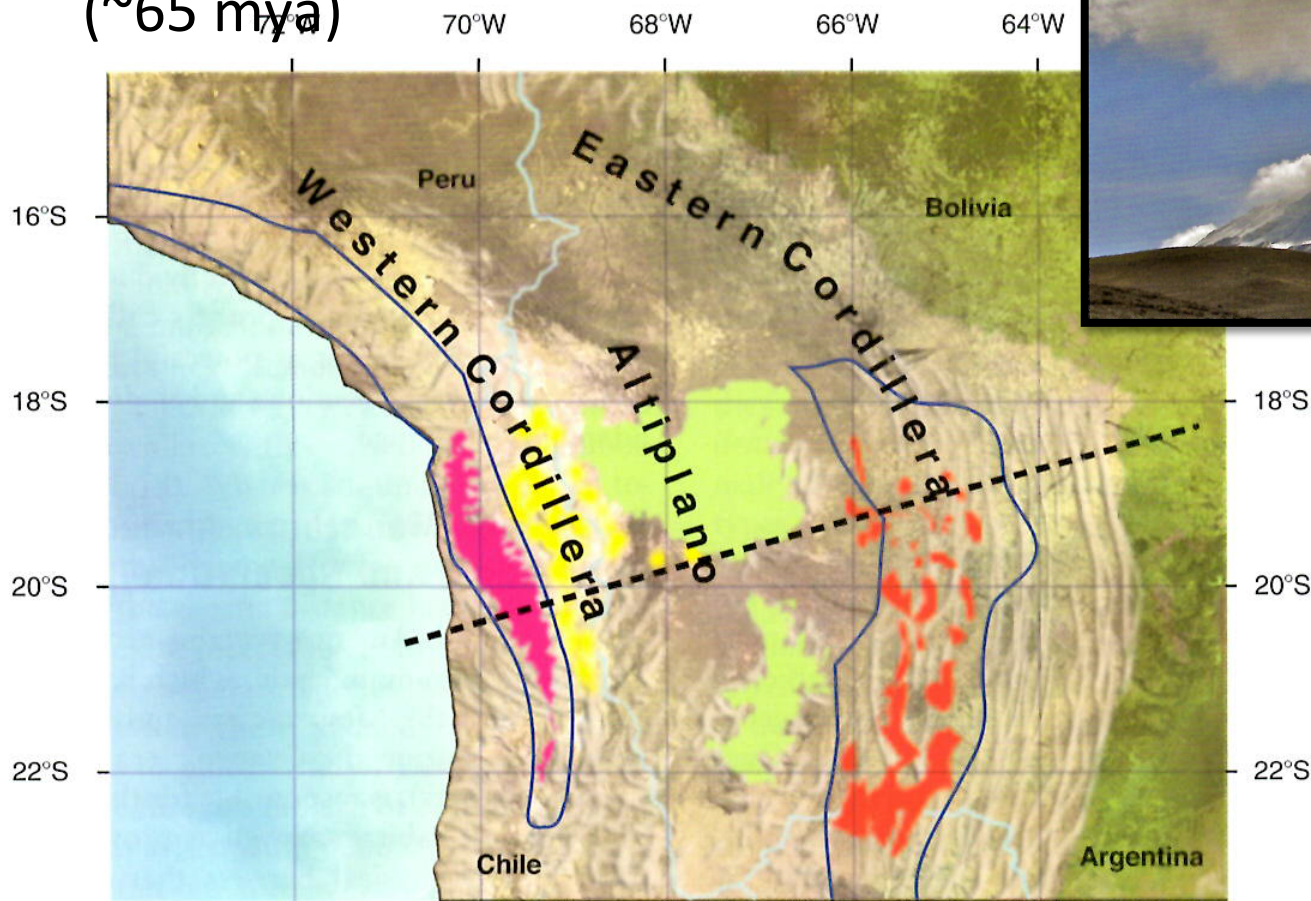


Much of the Andes consists of eastern and western cordilleras, separated by an expansive altiplano



# Andean/Amazonia Biogeography

Geological activity and Andean uplift during the Cenozoic era  
(~65 mya)



The resulting complex topography is the perfect geographic template to drive speciation

# Andean/Amazonia Biogeography

An example of vicariant speciation in tapirs.

Baird's tapir (*Tapirus bairdii*) is found in lowland forest on the west side of the Andes into Central America



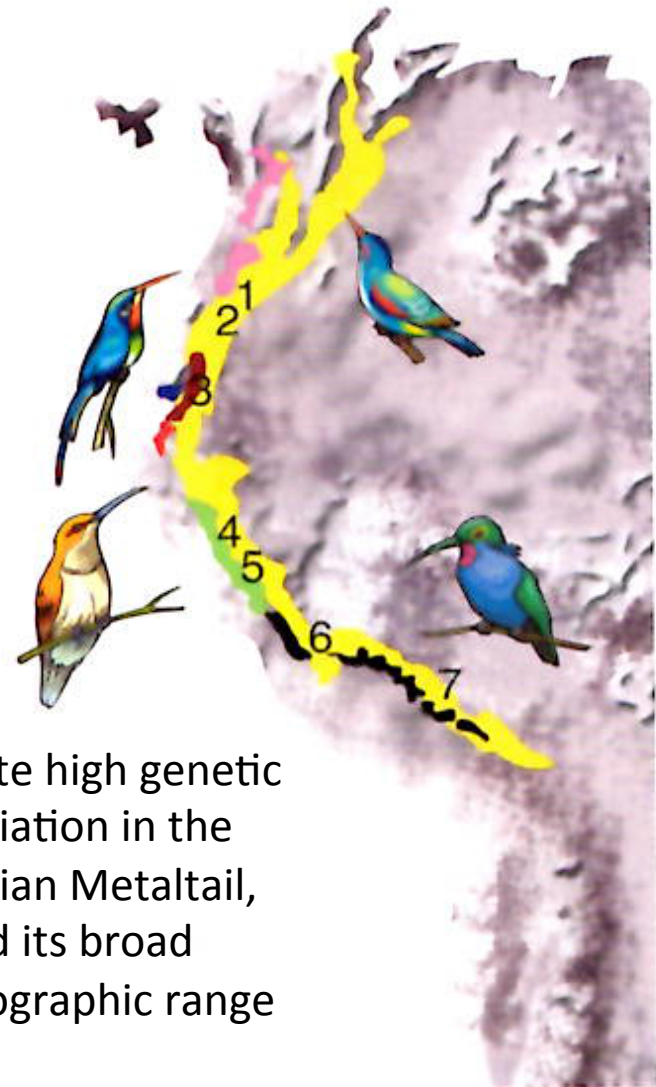
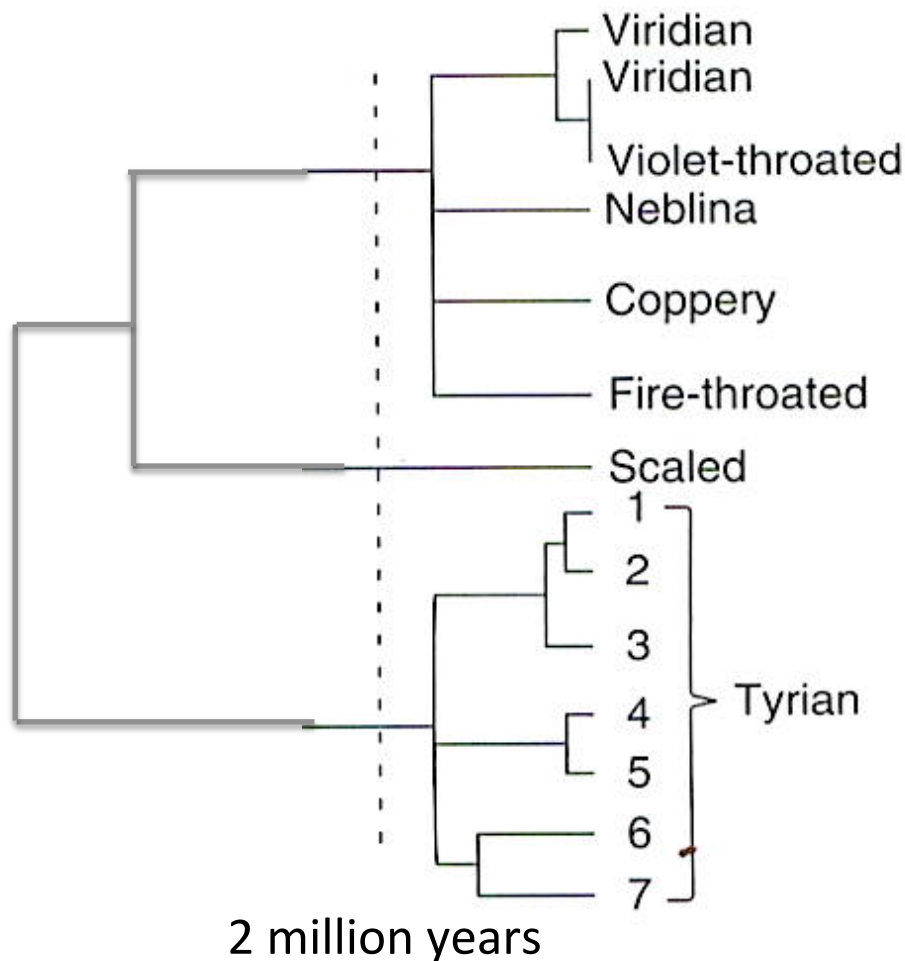
Brazilian tapir (*T. terrestris*) occurs in lowland forest on the east side of the Andes, occupying the Amazon basin

The Andes geographically isolates these species, and was probably the main barrier that initiated the split of the ancestral species.



# Andean/Amazonia Biogeography

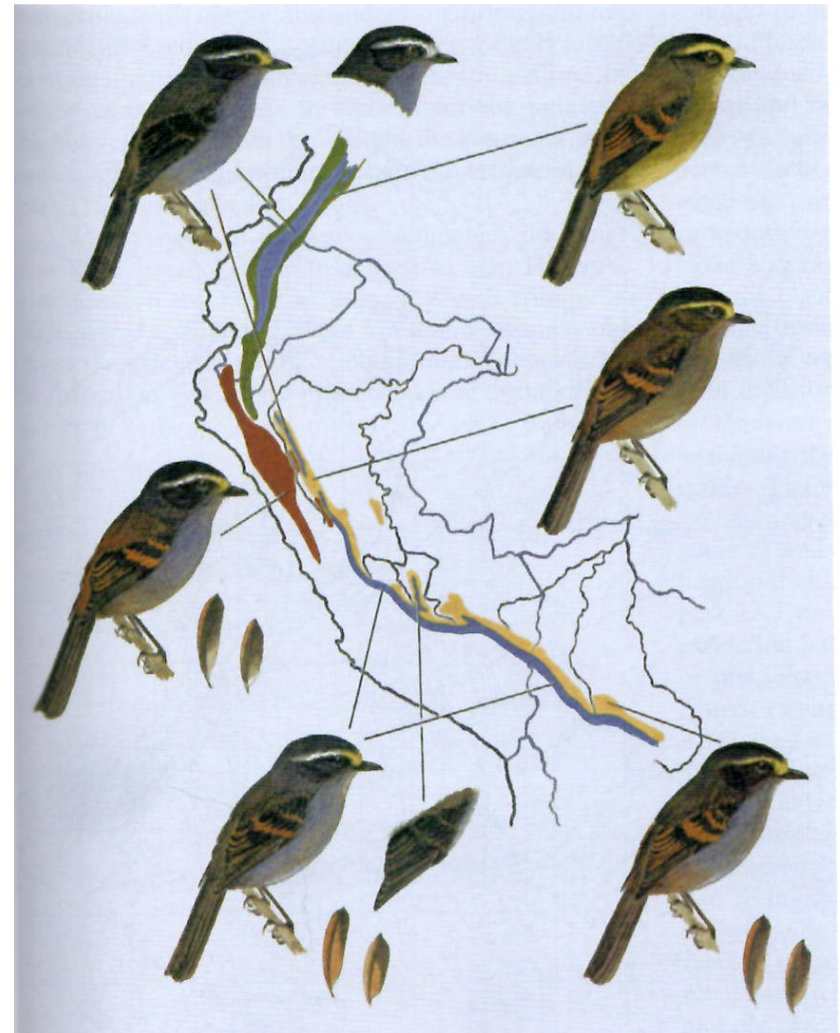
Phylogenetic relationships among Metaltail hummingbirds in the Andes



# Andean/Amazonia Biogeography

Chat-tyrants, a genus of Neotropical flycatchers, show complex differentiation across the Andes (Colombia to Bolivia) into *superspecies* groups – closely related, recently evolved clusters of species – on eastern and western Andean slopes

This pattern suggests that speciation was facilitated by Andean topography



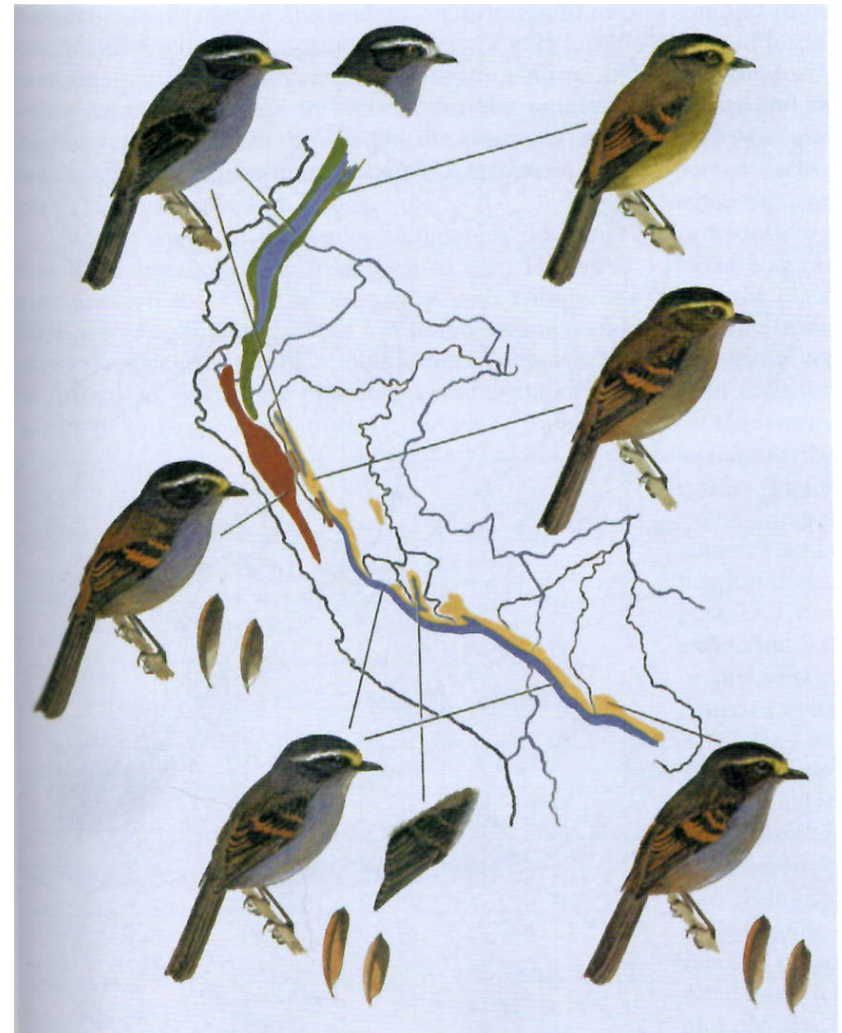
# Andean/Amazonia Biogeography

With groups of close relatives, we can ask:

When did these groups diversify?

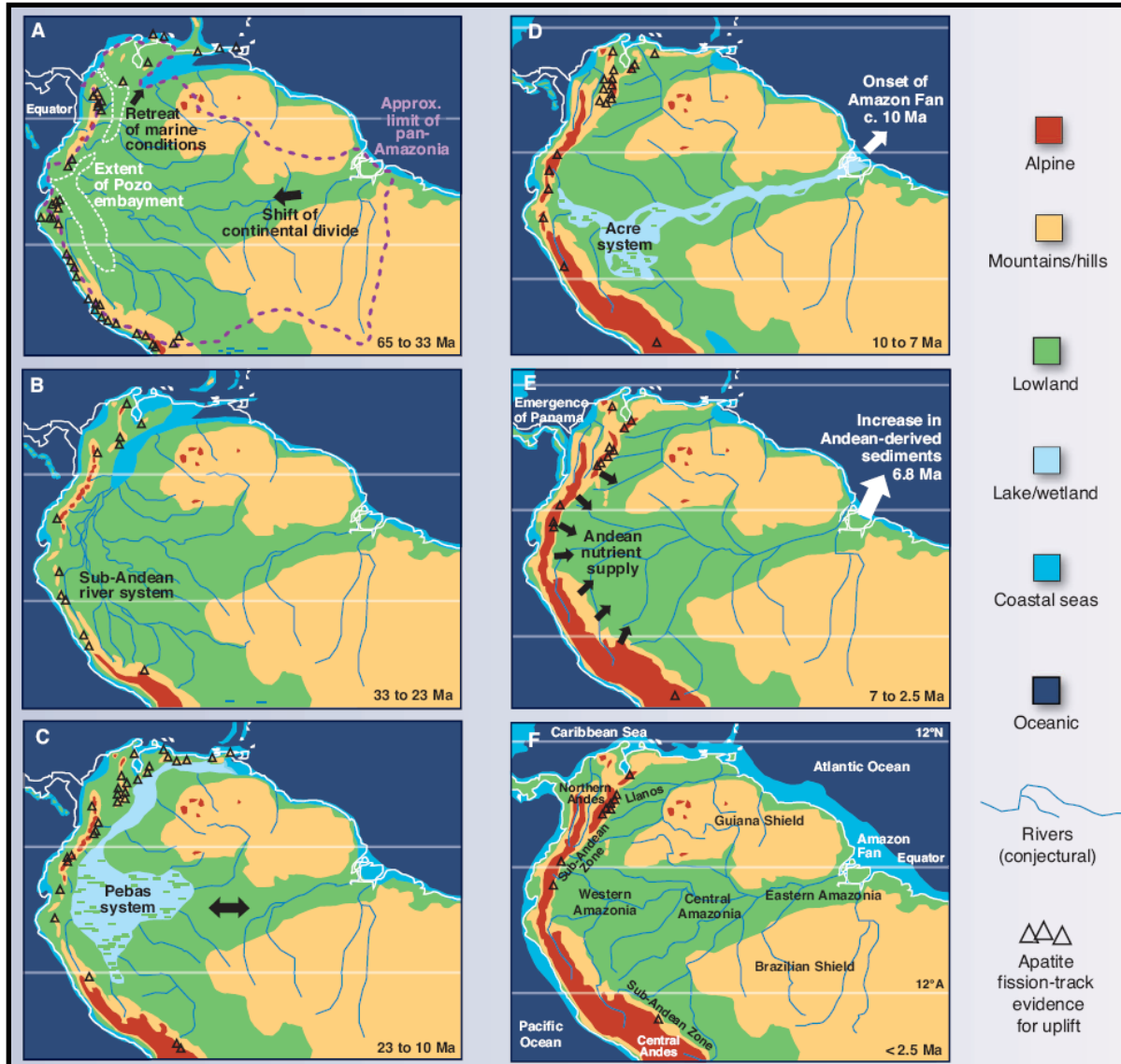
What were the biogeographic factors influencing diversification?

Using the timing of geographical events and species splits, and phylogenetic relationships among species, we can piece together likely scenarios for speciation



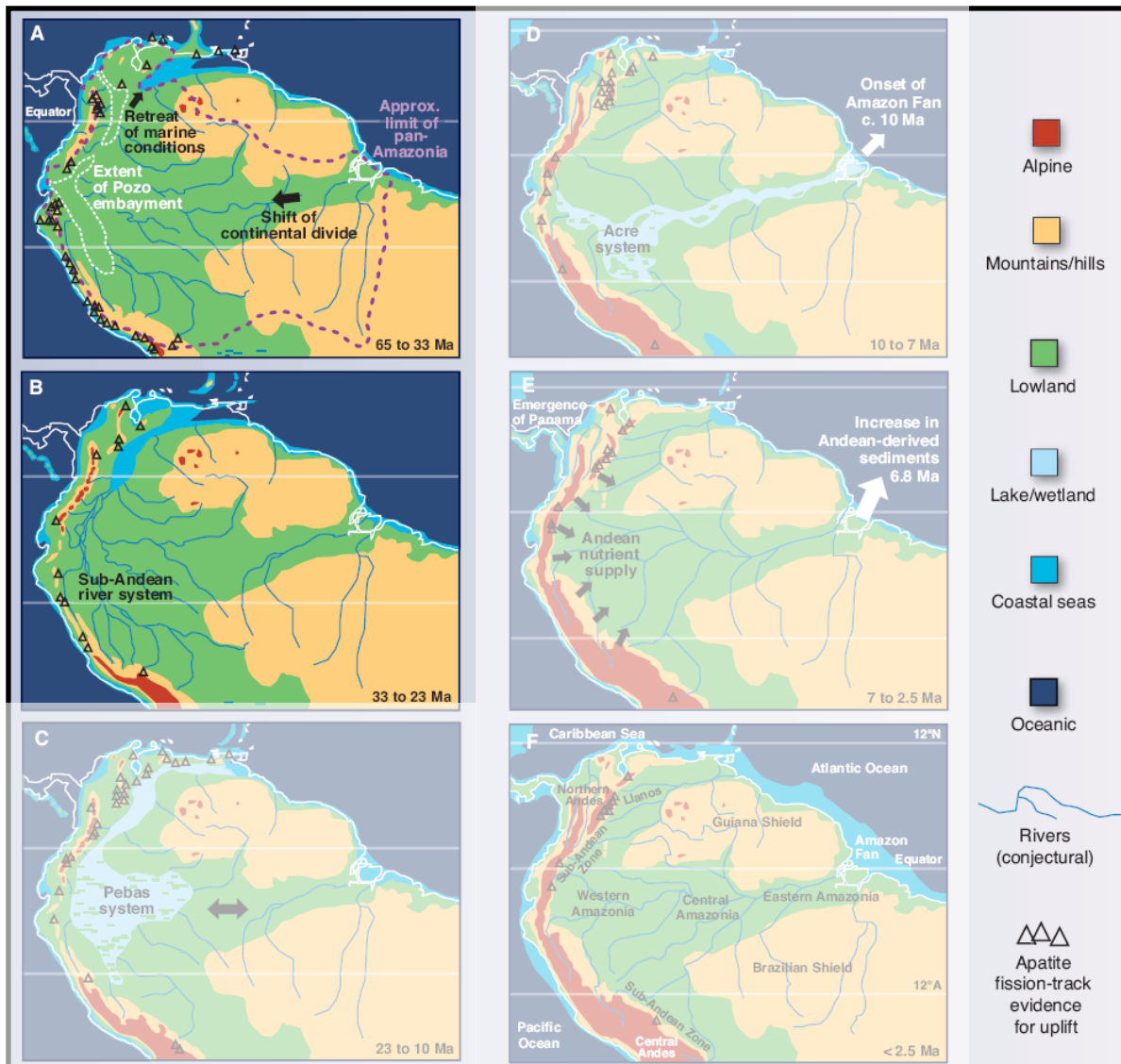


# Hypothesized historical biogeography of tropical South America



Hoorn et al. 2010, *Science*

# Hypothesized historical biogeography of tropical South America

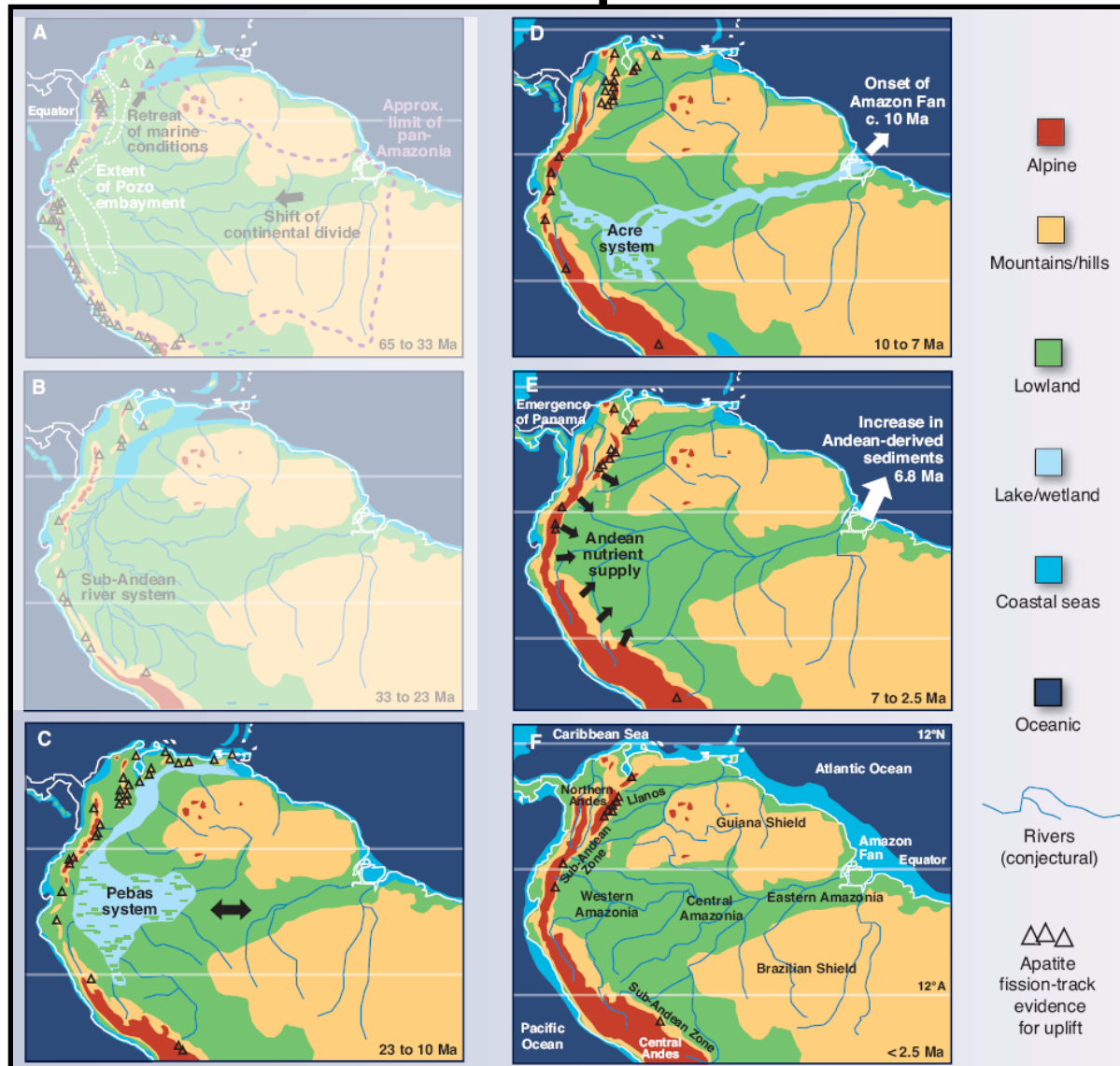


A – B:

Amazon “cratonic”  
dominated landscape



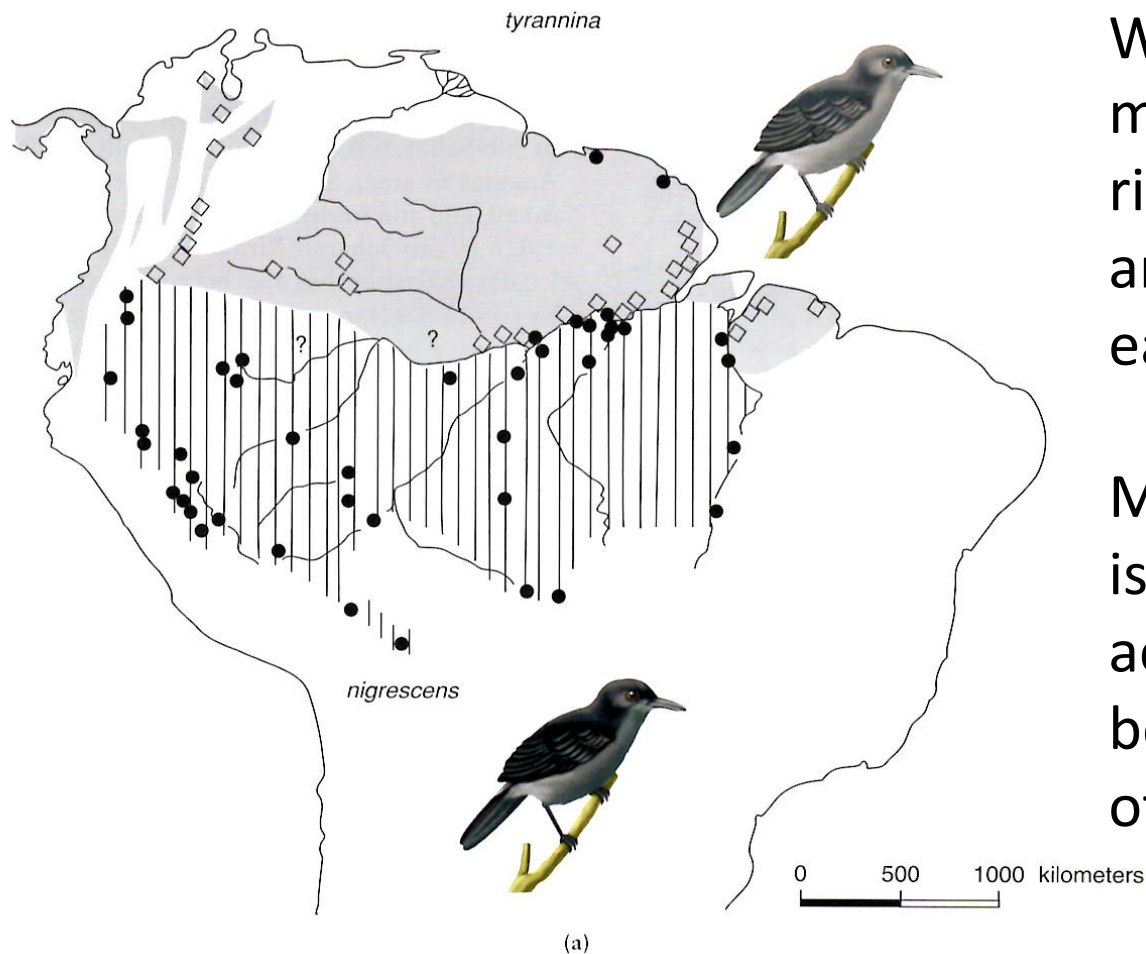
# Hypothesized historical biogeography of tropical South America



C – F:

“Andean” dominated landscape

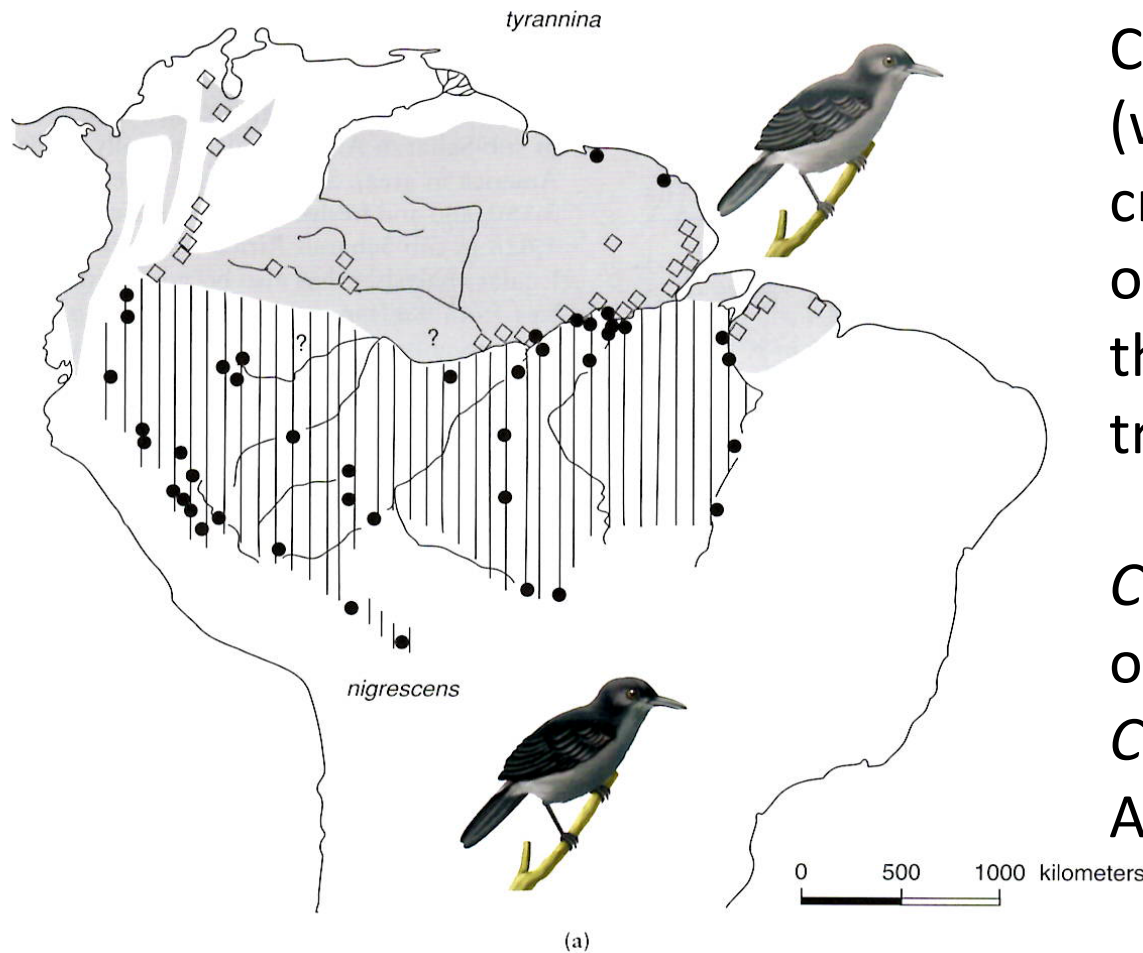
# Hypothesized historical biogeography of tropical South America



With the rise of the Andes mountains, the Amazon river system was created, and drainage shifted to the east

Many wide tributaries isolated tracts of forest across the Amazon, becoming important forces of geographic isolation

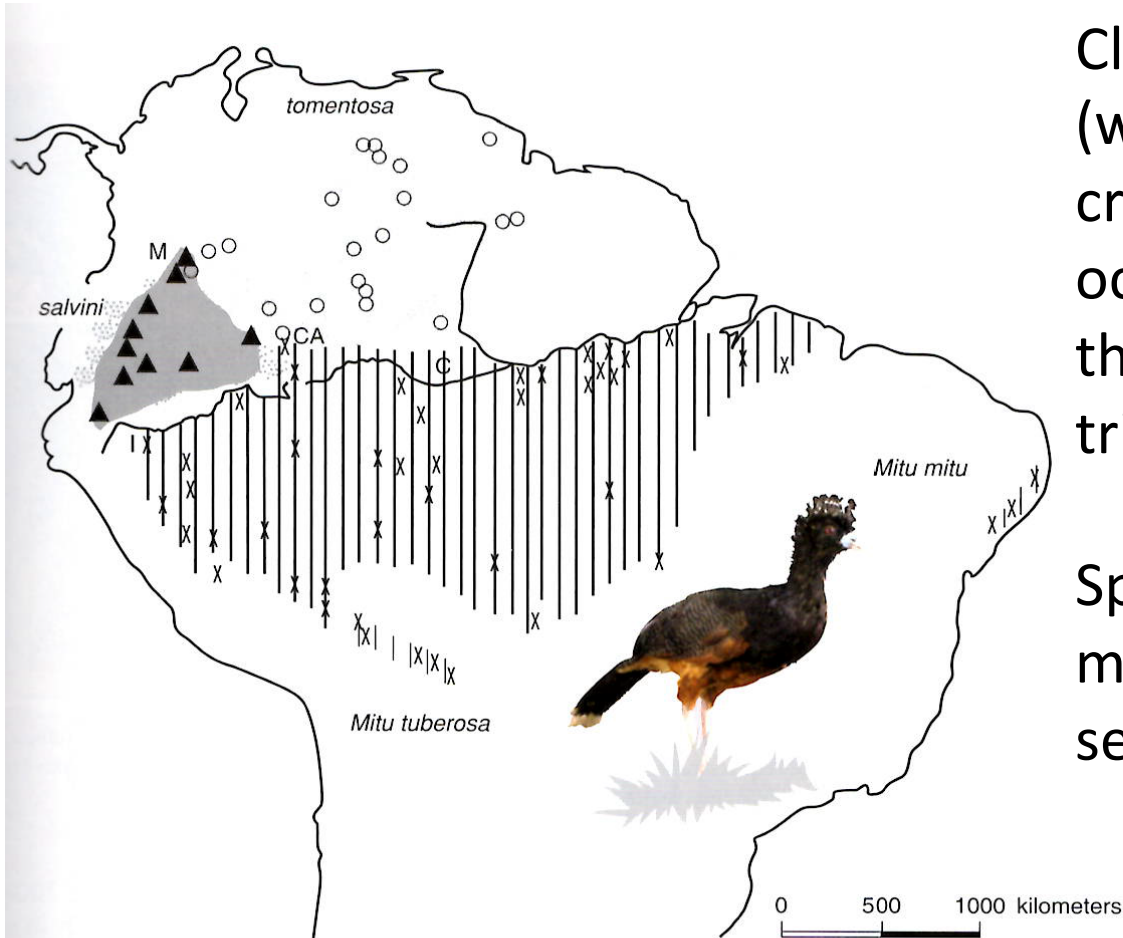
# Hypothesized historical biogeography of tropical South America



Closely related bird species (which are reluctant to cross large water bodies) occur on opposite sides of the Amazon and its tributaries

*Cercomacra tyrannina* occurs north, and *C. nigrescens* south of the Amazon river

# Hypothesized historical biogeography of tropical South America



(b)

Closely related bird species (which are reluctant to cross large water bodies) occur on opposite sides of the Amazon and its tributaries

Species of curassow are morphologically similar but separated regionally

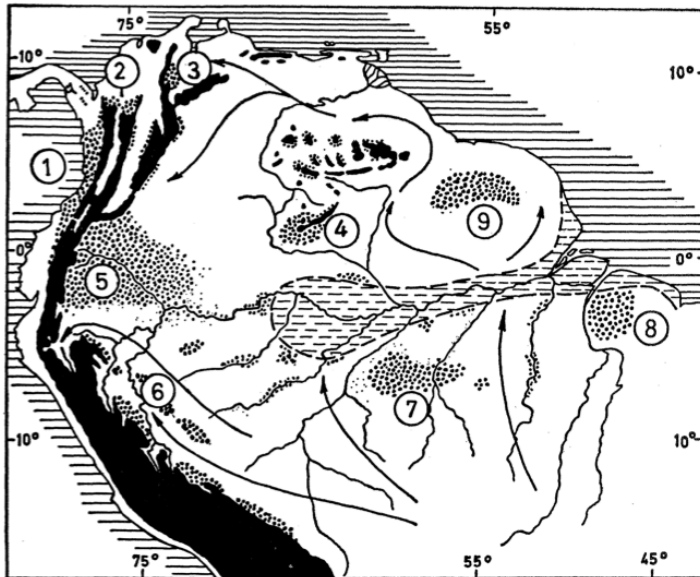


# Hypothesized historical biogeography of tropical South America

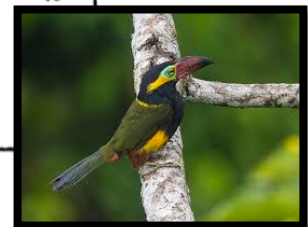
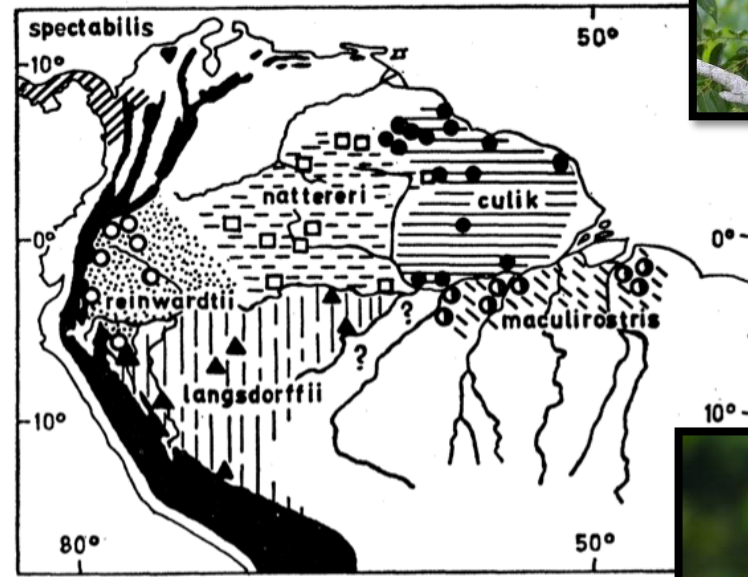
Since the 1970's there have been debates about the origins and timing of diversification of species in South America

Did most speciation occur during the Pleistocene, or long before?

Pleistocene rainforest refugia



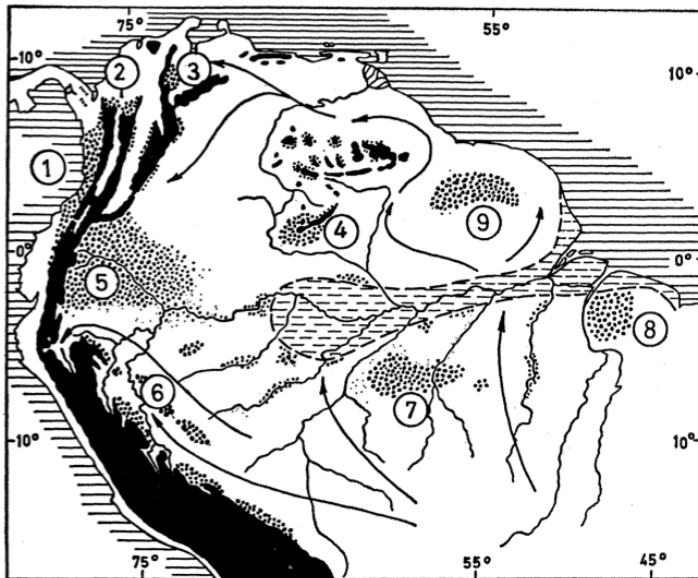
Distribution of *Selenidera* (toucanets)



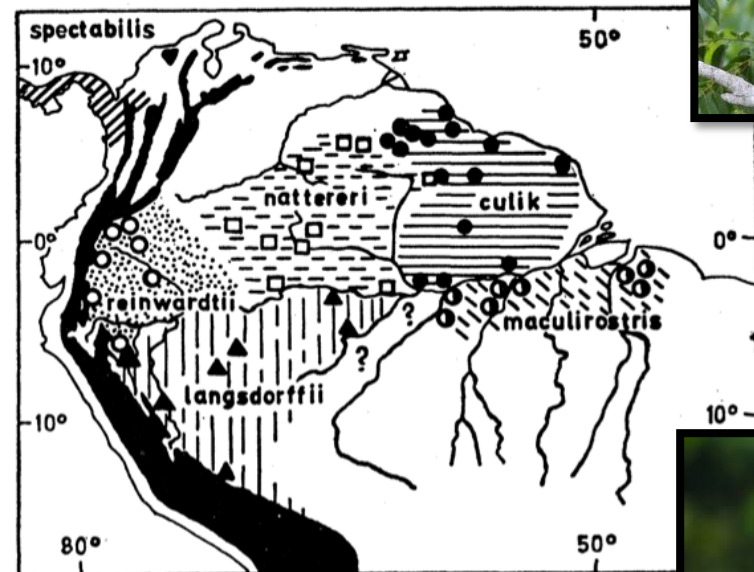
# Hypothesized historical biogeography of tropical South America

It is unlikely that the tropics were climatically stable during the Pleistocene (1.64 mya to 10,000 years ago), while glaciers covered large expanses of temperate landmasses.

Pleistocene rainforest refugia



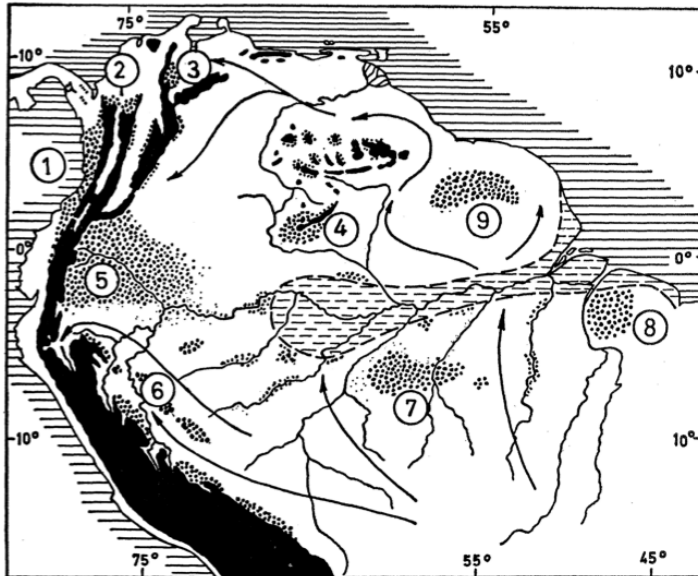
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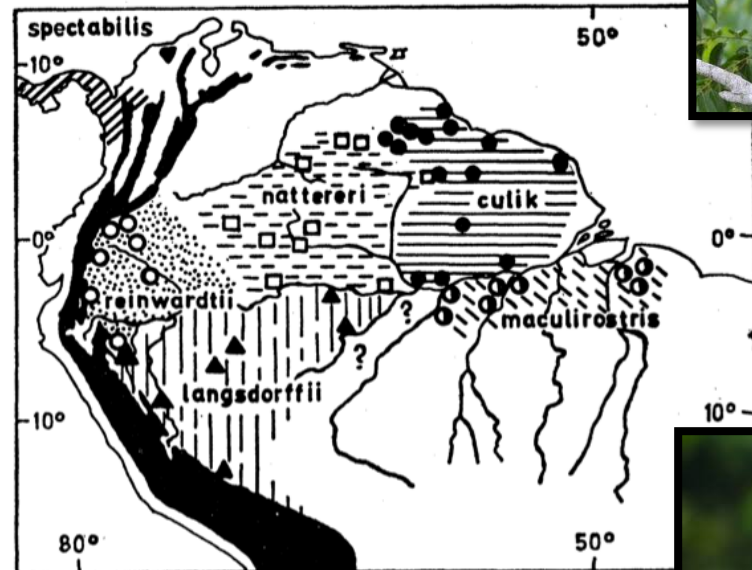
# Hypothesized historical biogeography of tropical South America

Refugia hypothesis (Haffer 1969): Glacial advances in the temperate zone made the tropics cooler and drier, and lowland rain forest persisted as islands during glacial maxima, surrounded by expansive grassland. This cyclical vicariance could have repeatedly fragmented populations of species during dry glacial periods.

Pleistocene rainforest refugia

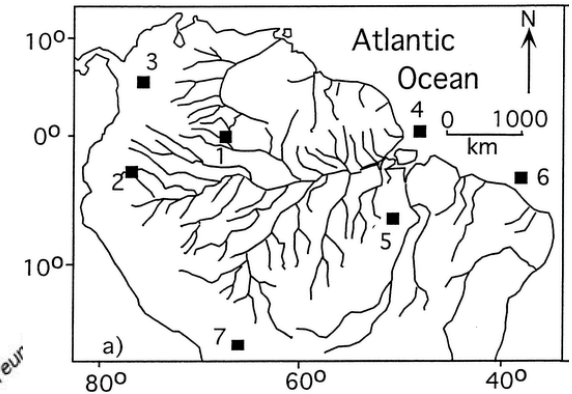


Distribution of *Selenidera* (toucanets)

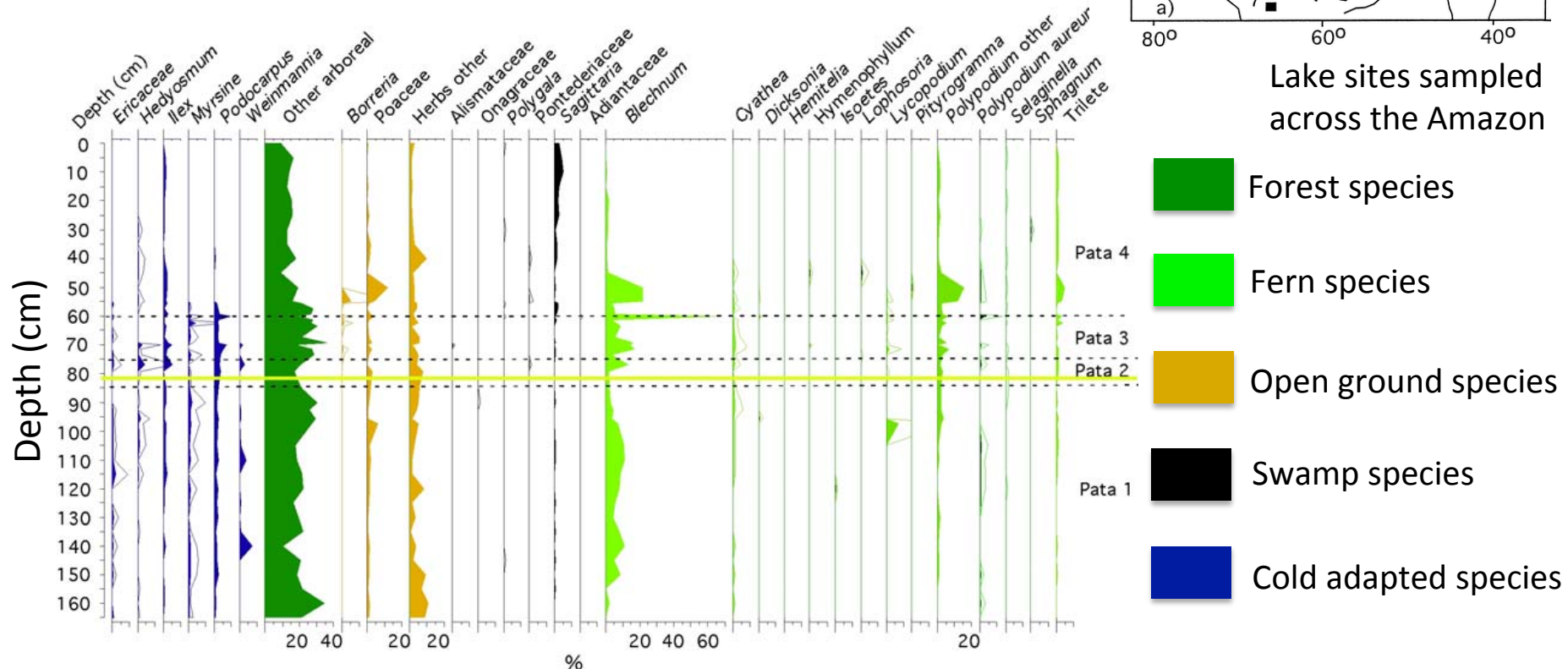


# Hypothesized historical biogeography of tropical South America

The refugia model has been subject to strong criticism. The hypothesis was largely based on inferences from current species distribution patterns, *not based* on paleoecological data.



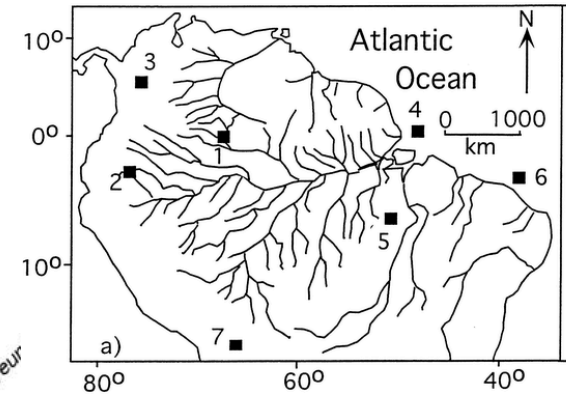
Lake sites sampled across the Amazon



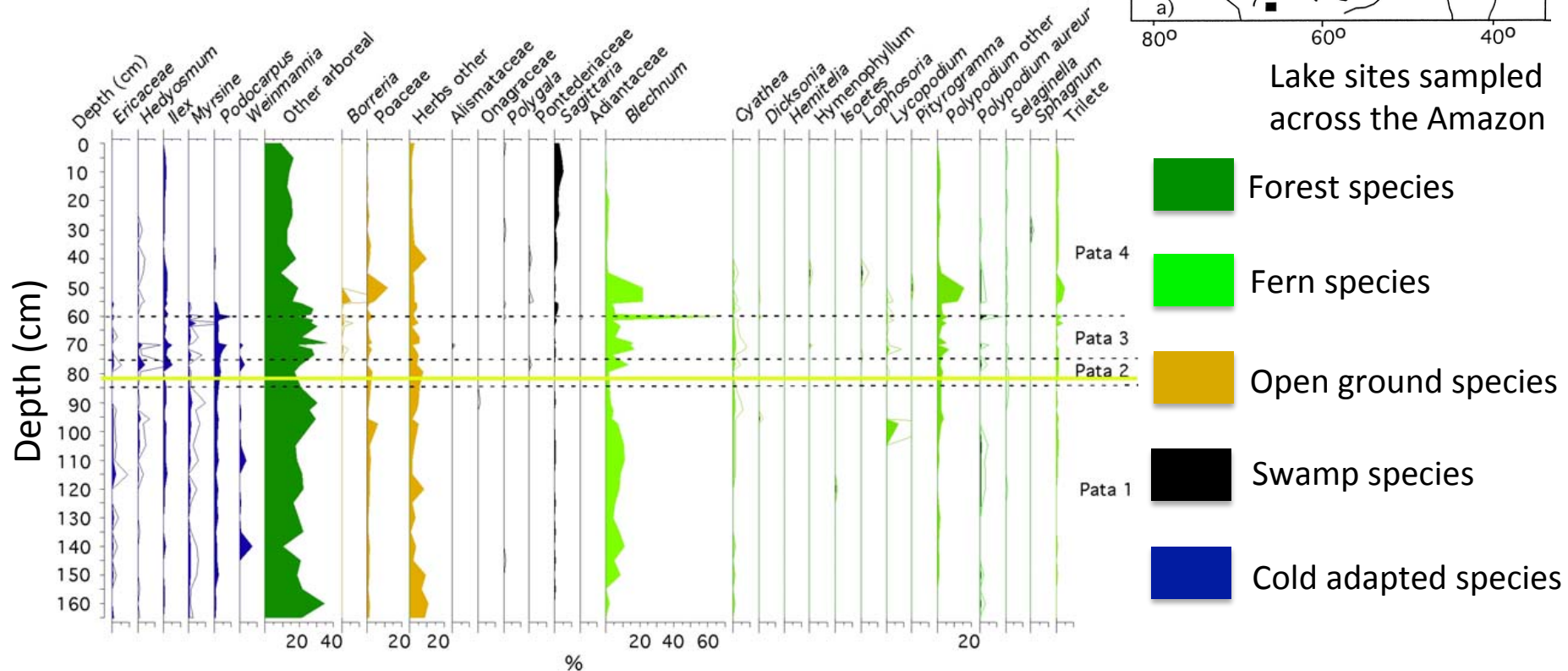


# Hypothesized historical biogeography of tropical South America

Fossil pollen data from lake cores show continuous forest cover and invasion by cold-adapted species during last glacial maximum.

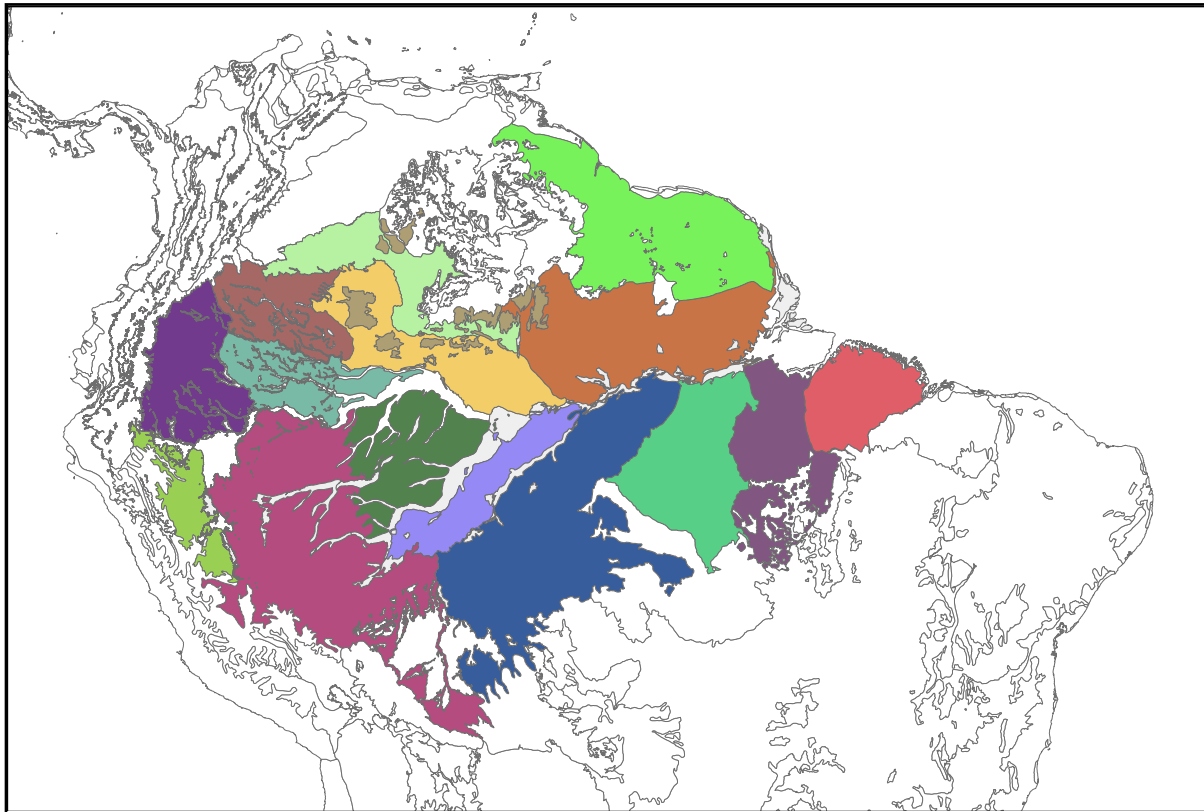


Lake sites sampled across the Amazon



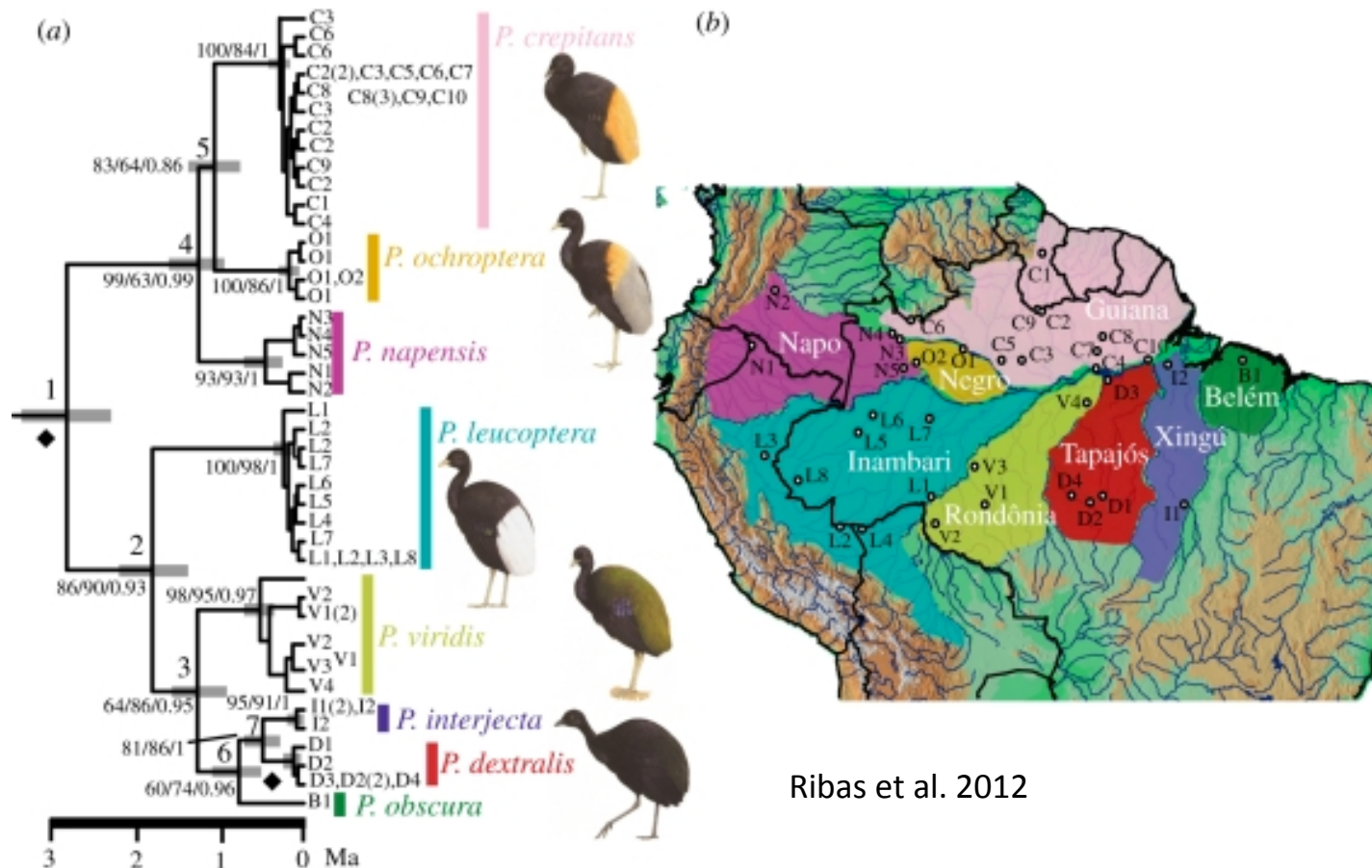
# Hypothesized historical biogeography of tropical South America

Amazonian Ecoregions divided by large river systems are also consistent with range limits across many species groups and represent areas of endemism for birds in South America



# Hypothesized historical biogeography of tropical South America

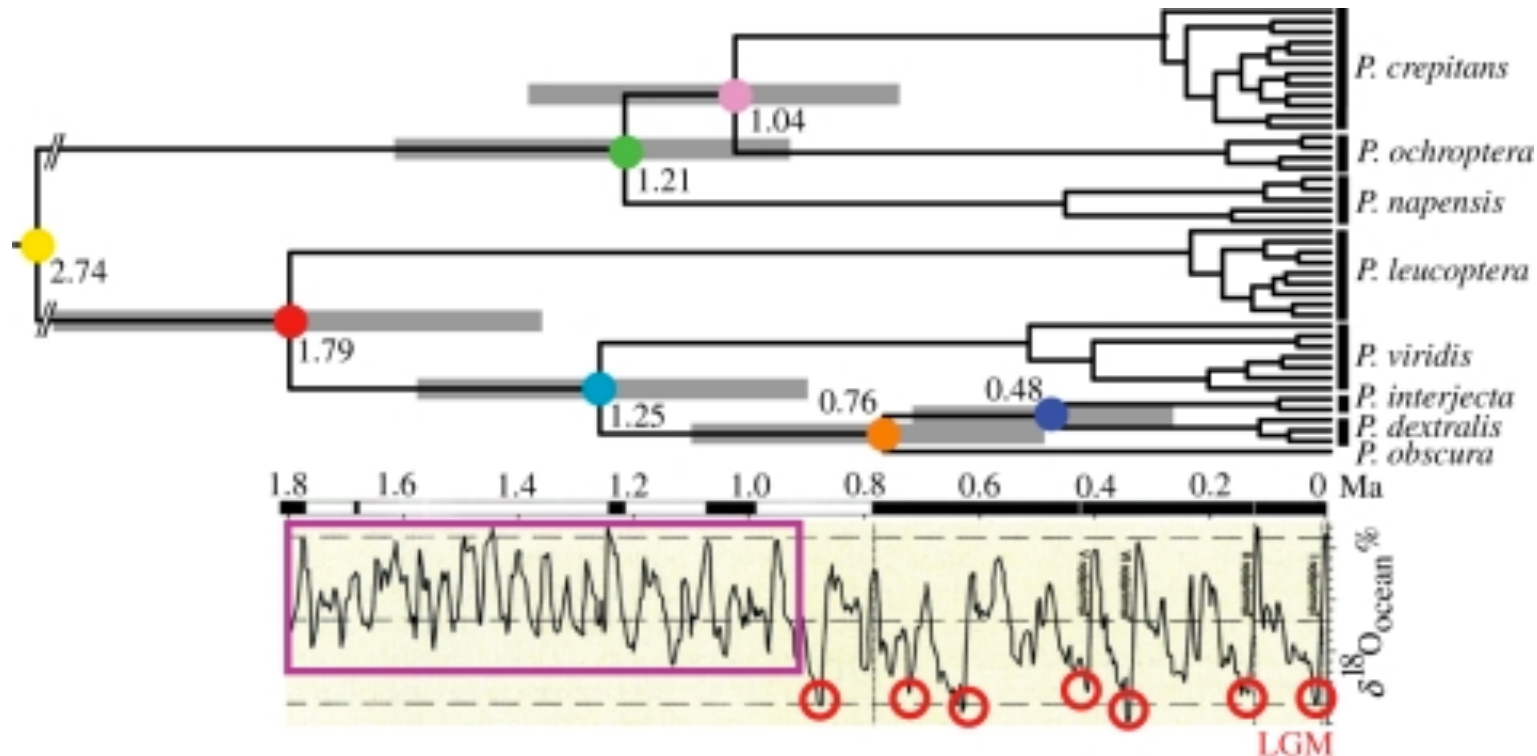
Phylogenetic relationships of trumpeter species in South America. Species distributions are separated by large river systems.



Ribas et al. 2012

# Hypothesized historical biogeography of tropical South America

Timing of diversification events indicates speciation events occurred prior to most recent glacial maxima.





# Hypothesized historical biogeography of tropical South America

## Hypothesis for diversification of trumpeters following establishment of river barriers

a) 3.0 – 2.7 mya: western lowland Amazon is a large interconnected wetland system

b) 2.7 – 2.0 mya: wetland system drained and lower Amazon River was established

c) 2.0 – 1.0 mya: Rio Madeira drainage established

d) 1.3 – 0.8 mya: Rio Tapajos drainage established

e) 1.0 – 0.7 mya: isolating barrier with lower Rio Negro formed

f) 0.8 – 0.3 mya: two drainage systems on Brazilian shield (Rio Tocantins and Xingu) established

