Relationships of Floras (& Faunas)

Knowledge of earth and organism histories now permit closer examination of relationships of disjunct floras and faunas

- Southern Hemisphere temperate
- Southern Hemisphere tropics
- the Wallace Line
- Eastern Asian - Eastern North American temperate

Vicariance vs. Dispersal
how do you decide?

Biogeography has relied on two sources of information

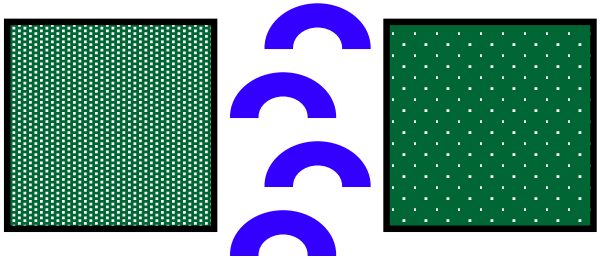
1. **Phylogenetic trees - clades**

2. **Knowledge of splitting events of areas - continents, mountain erection, etc.**

What is missing?

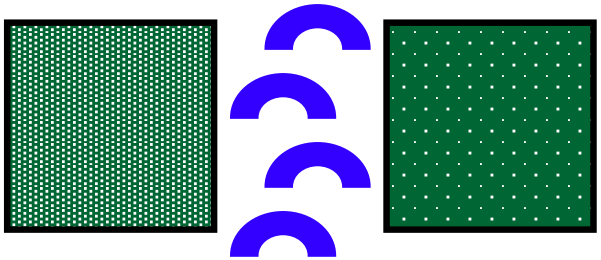
3. Times for branching events of clades relative to geological event – clocks!

Vicariance



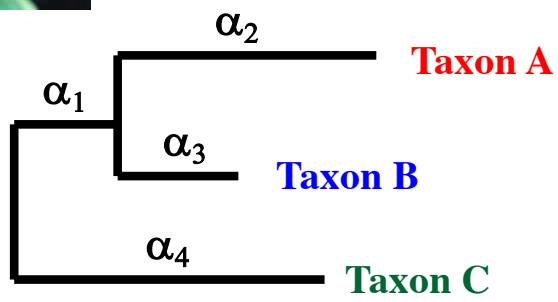
Disjunct (vicariad) species
Disjunct continental areas

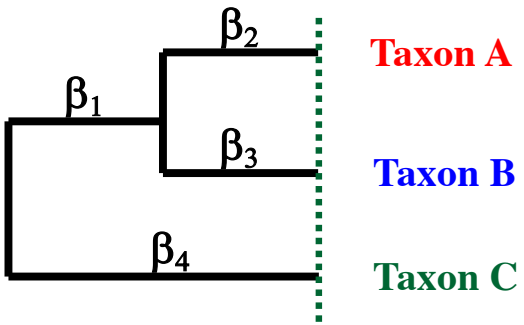
Dispersal



Disjunct species
Disjunct continental areas

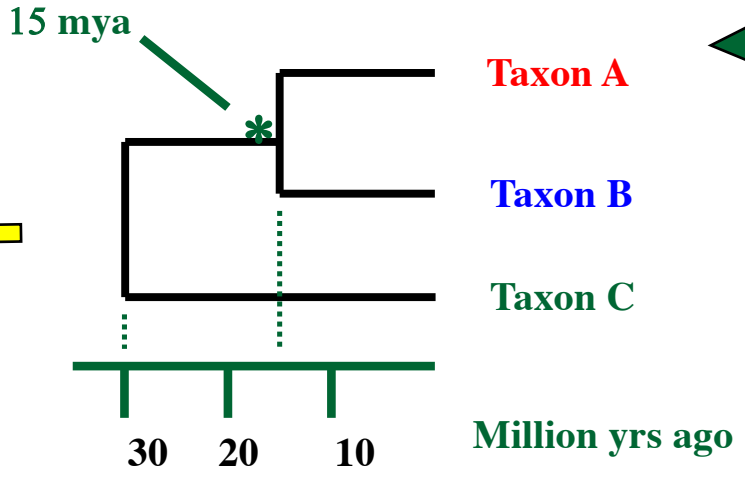
Continents, Clades, and Clocks

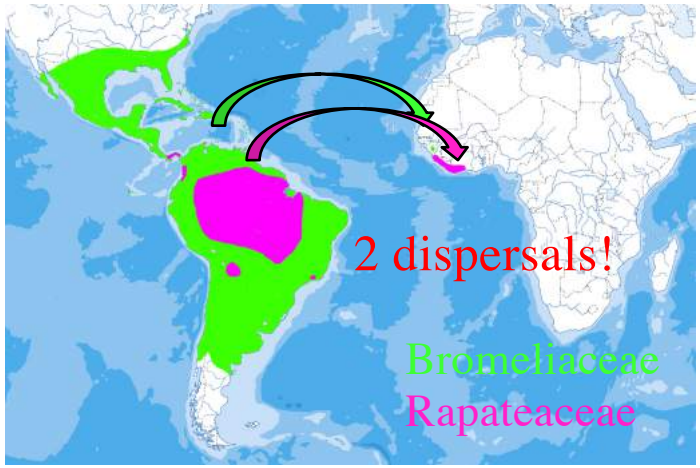




Maximum likelihood tree with different DNA rates along each branch

DNA "rate smoothed" tree





Biogeographical interpretation

***Fossil calibrated tree**

Relationships of Floras & Faunas

Knowledge of earth and organism histories now permit closer examination of relationships of disjunct floras and faunas

- Southern Hemisphere temperate
- Southern Hemisphere tropics
- the Wallace Line
- Eastern Asian - E N American temperate

Southern Hemisphere Temperate Flora

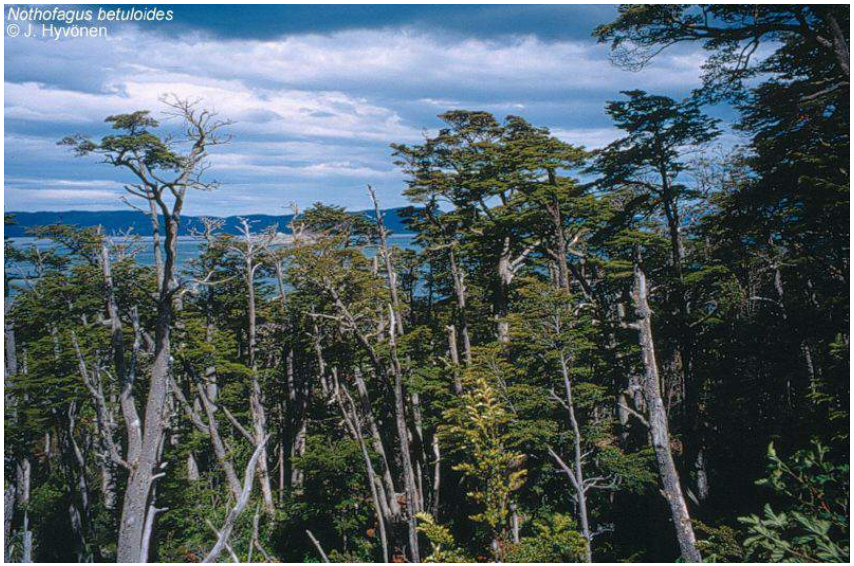
Interesting contrast between the floras of the southern hemisphere temperate and tropical floras.

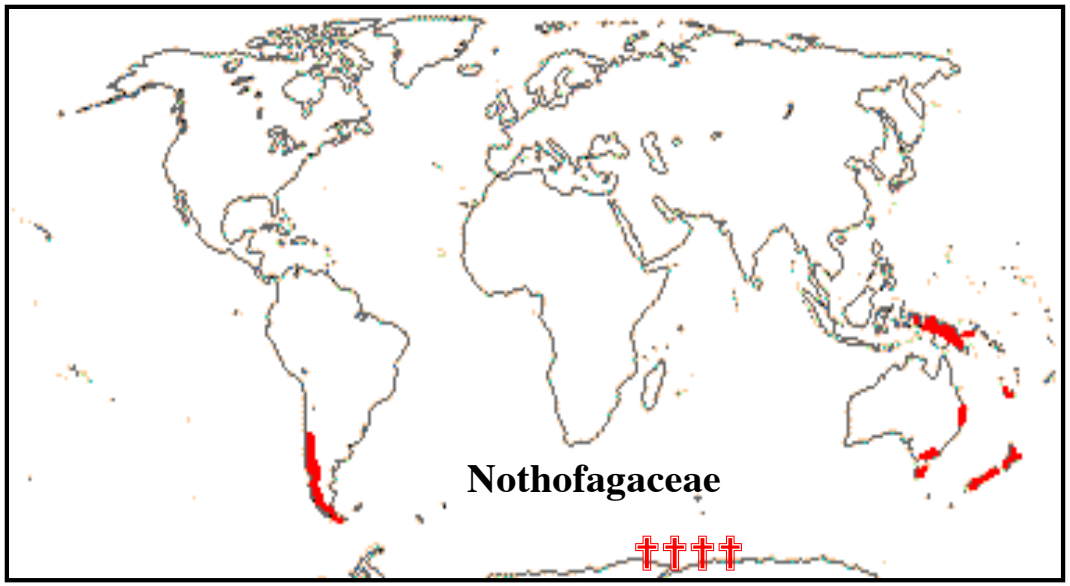
[The northern hemisphere continents are far more affected by recent glaciation events, so their distribution patterns are far more complex].

Southern Hemisphere Temperate Flora

35 species of trees and shrubs, evergreen and deciduous, restricted to South America, New Zealand, Australia, Tasmania, New Caledonia, New Guinea, and fossilized in Antarctica

Absent from Africa! — "odd continent out"

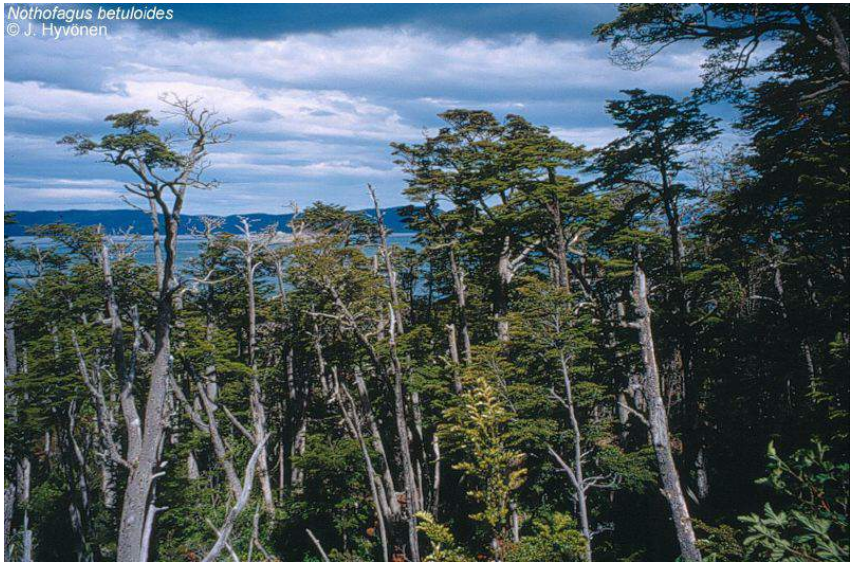


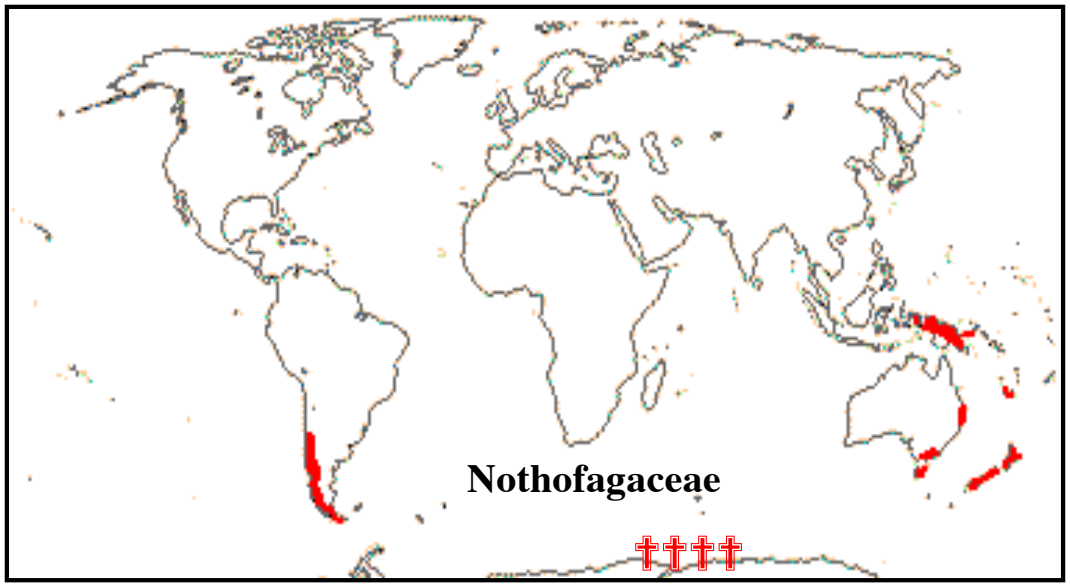


Southern Hemisphere Temperate Flora

Connections between South America and Australasia pronounced:

- Subg. *Nothofagus* — South America
- Subg. *Fuscospora* — S. Am., N. Zeal., Tasmania
- Subg. *Lophozonia* — S. Am., N. Zeal., Tasmania, Austr.
- Subg. *Brassospora* — New Caledonia, New Guinea



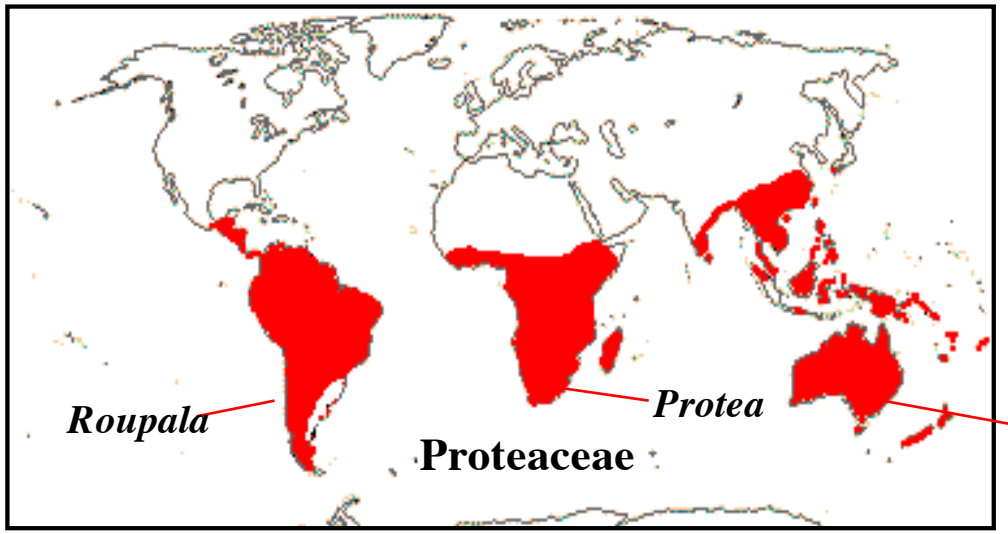


Southern Hemisphere Temperate Flora

Proteaceae comprise 1700 species of woody plants placed in 79 genera predominantly of the southern hemisphere. The family, unlike Nothofagaceae, occurs in south Africa and Madagascar, and extends into southern China.

The 16 genera from Africa are endemic and comprise only 3 lineages. In comparison, South America and Australasia share roughly half of the genera in common. All tribes within the latter two areas are shared.

Africa — "odd continent out"!



Southern Hemisphere Temperate Flora

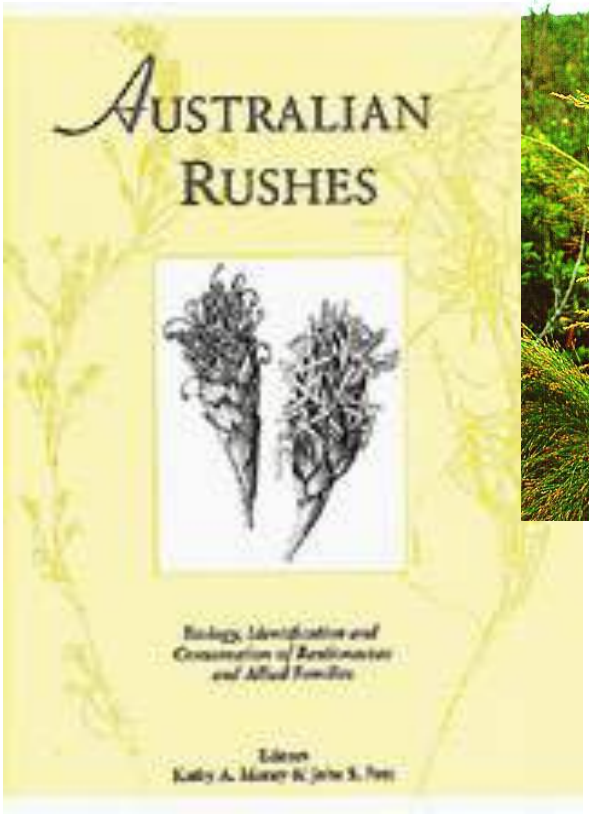
Restionaceae comprise 520 species of grass-like plants placed in 58 genera predominantly of the southern hemisphere.

Askidiosperma — Restionaceae
Cape Region

Southern Hemisphere Temperate Flora

Restionaceae comprise 520 species of grass-like plants placed in 58 genera predominantly of the southern hemisphere.

The 350 species from Africa are unique and belong only to 11 genera of the *Restio* group. In contrast, South America and Australasia share many genera including some species. Africa — "odd continent out"!



Fynbos, S. Africa
— Restionaceae

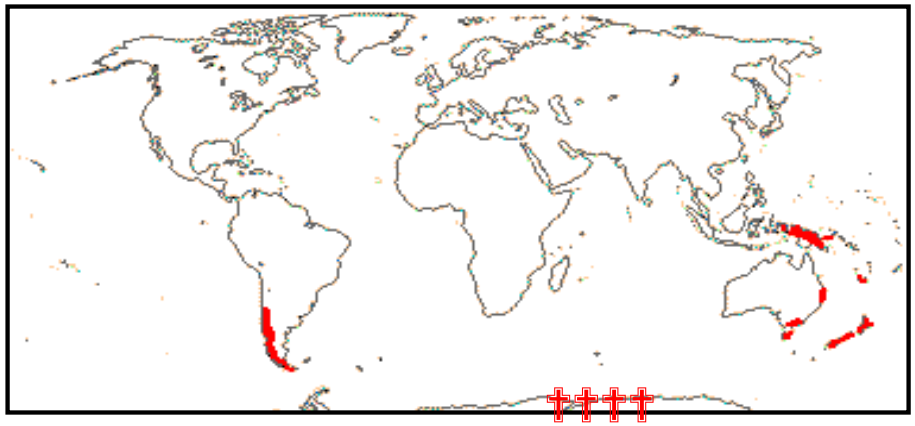
Southern Hemisphere Temperate Flora

Why is Africa the "odd continent out" when it comes to the *temperate* southern hemisphere flora?

Three reasons:

Proteaceae

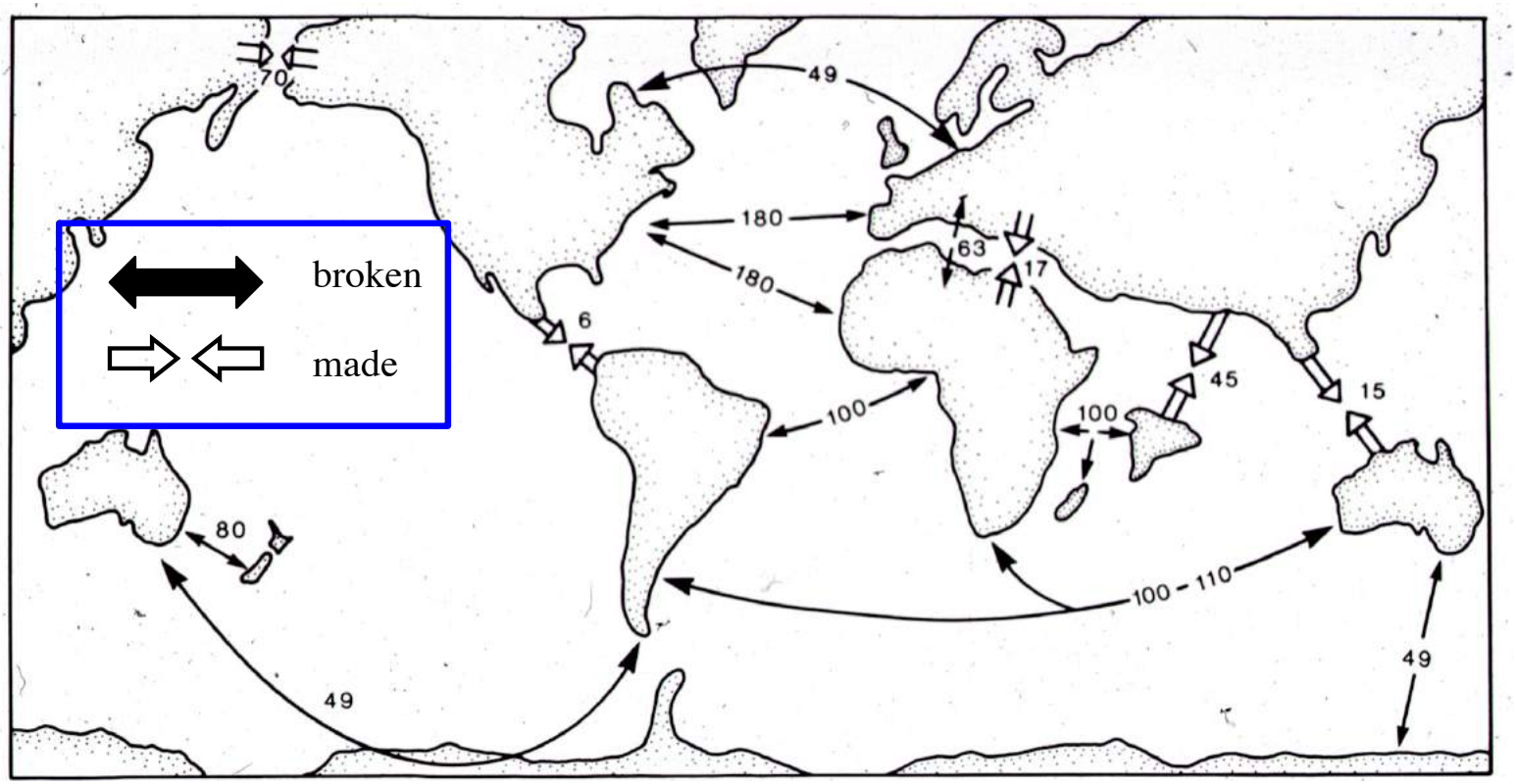
Restionaceae



Nothofagaceae

Southern Hemisphere Temperate Flora

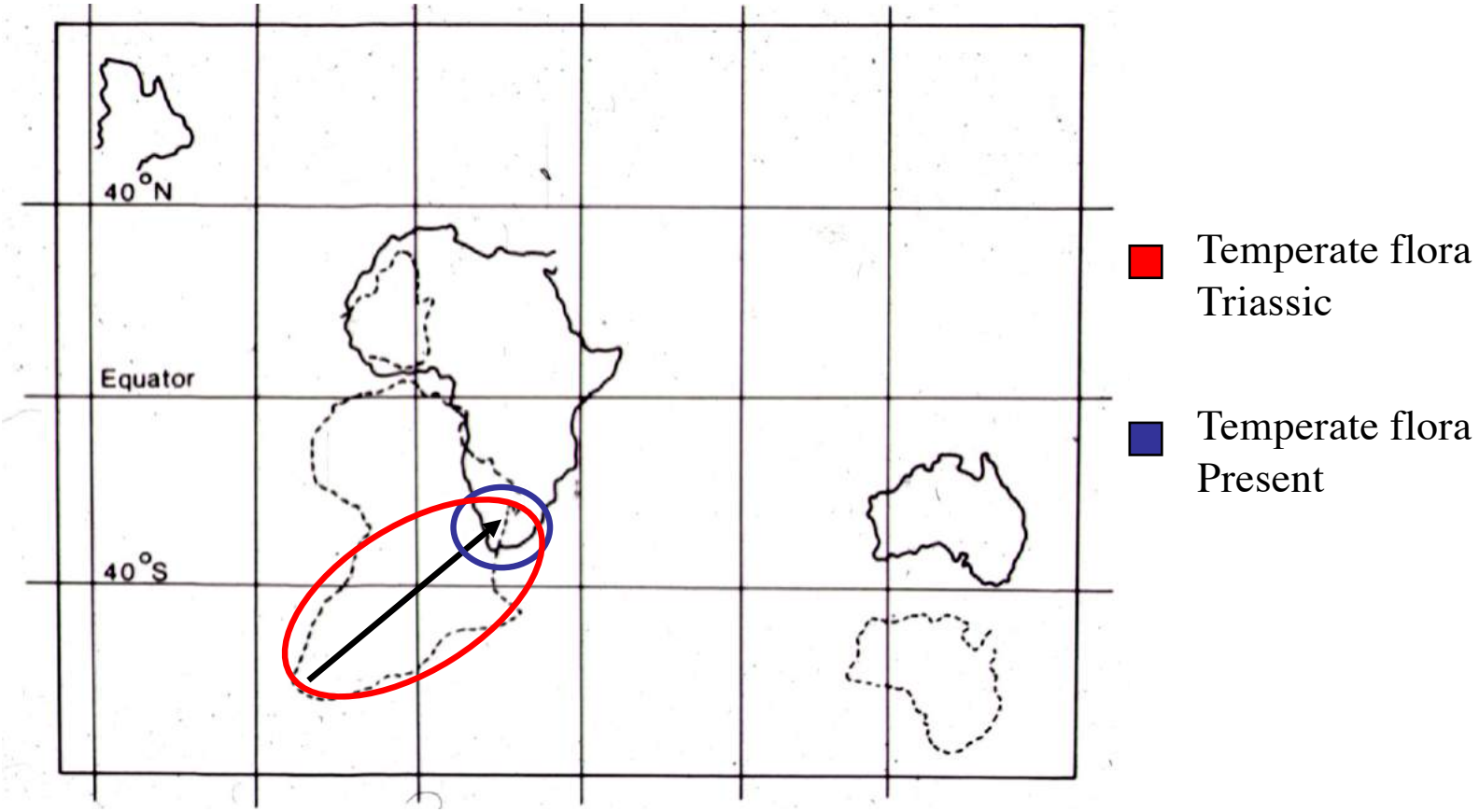
1. All three continents separated from Gondwana at about 100-110 mya in the early Cretaceous, but South America and Australia linked with temperate Antarctica until about 50 mya (and via small water passages until 27 mya)



Estimates in millions of years BP when migration routes between land masses were broken or made.

Southern Hemisphere Temperate Flora

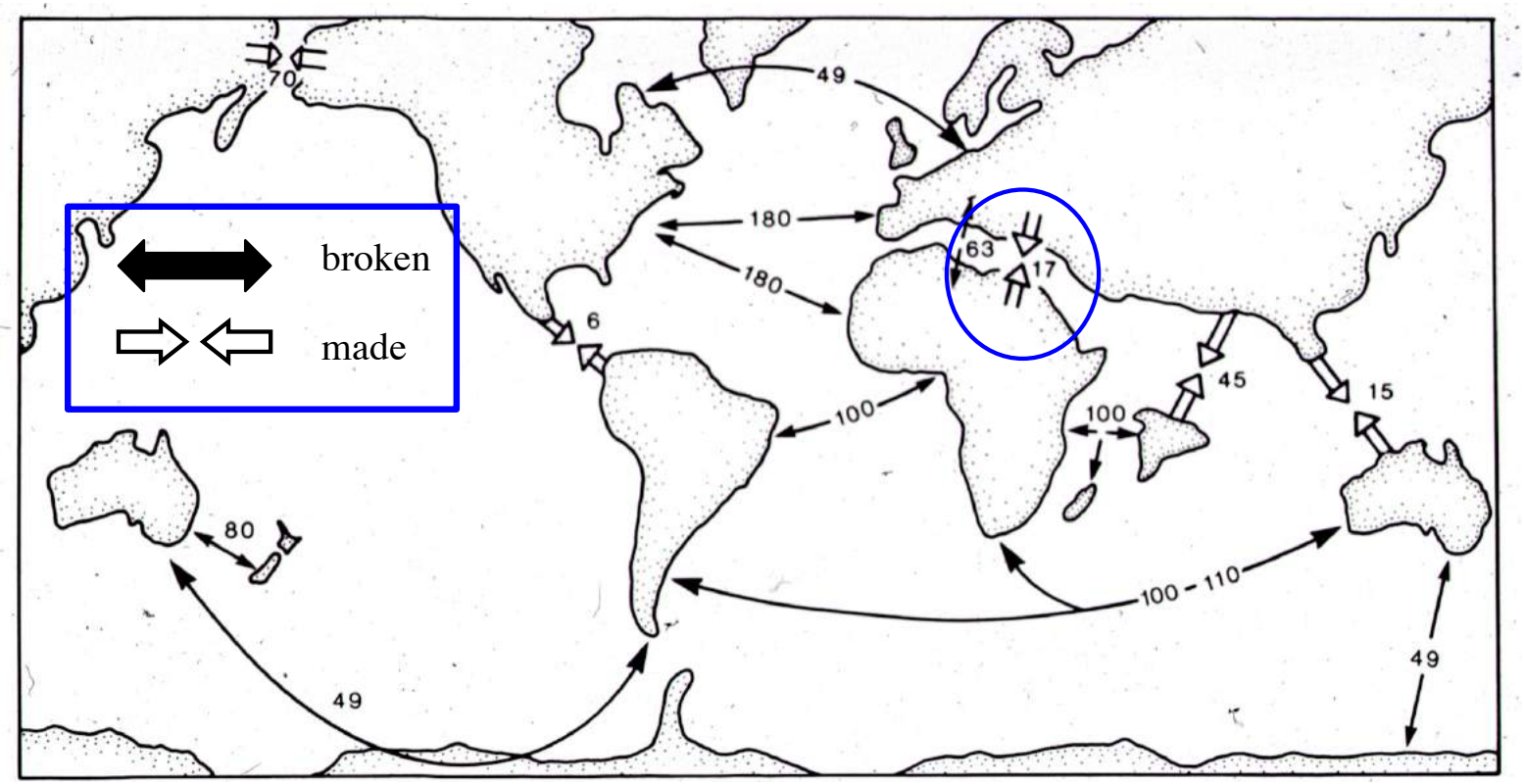
2. Africa drifted further north and experienced greater climatic change through this latitudinal journey. Greater extinction of temperate biota; which is now restricted to small area of south Africa.



Positions of Labrador, Africa, and Australia in the Triassic (200 mya) and at the present

Southern Hemisphere Temperate Flora

3. Africa made secondary contact with temperate Eurasia around 17 mya; long contact further differentiated the temperate flora of Africa relative to South America and Australia



Estimates in millions of years BP when migration routes between land masses were broken or made.

Vicariance vs. Dispersal?

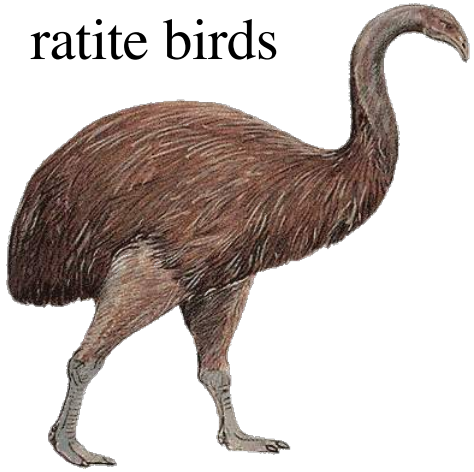
Temperate Gondwanan disjuncts – vicariance and/or dispersal ?

Timing of organism divergence vs. timing of geological divergence critical

marsupials

Nothofagus
southern beeches

ratite birds

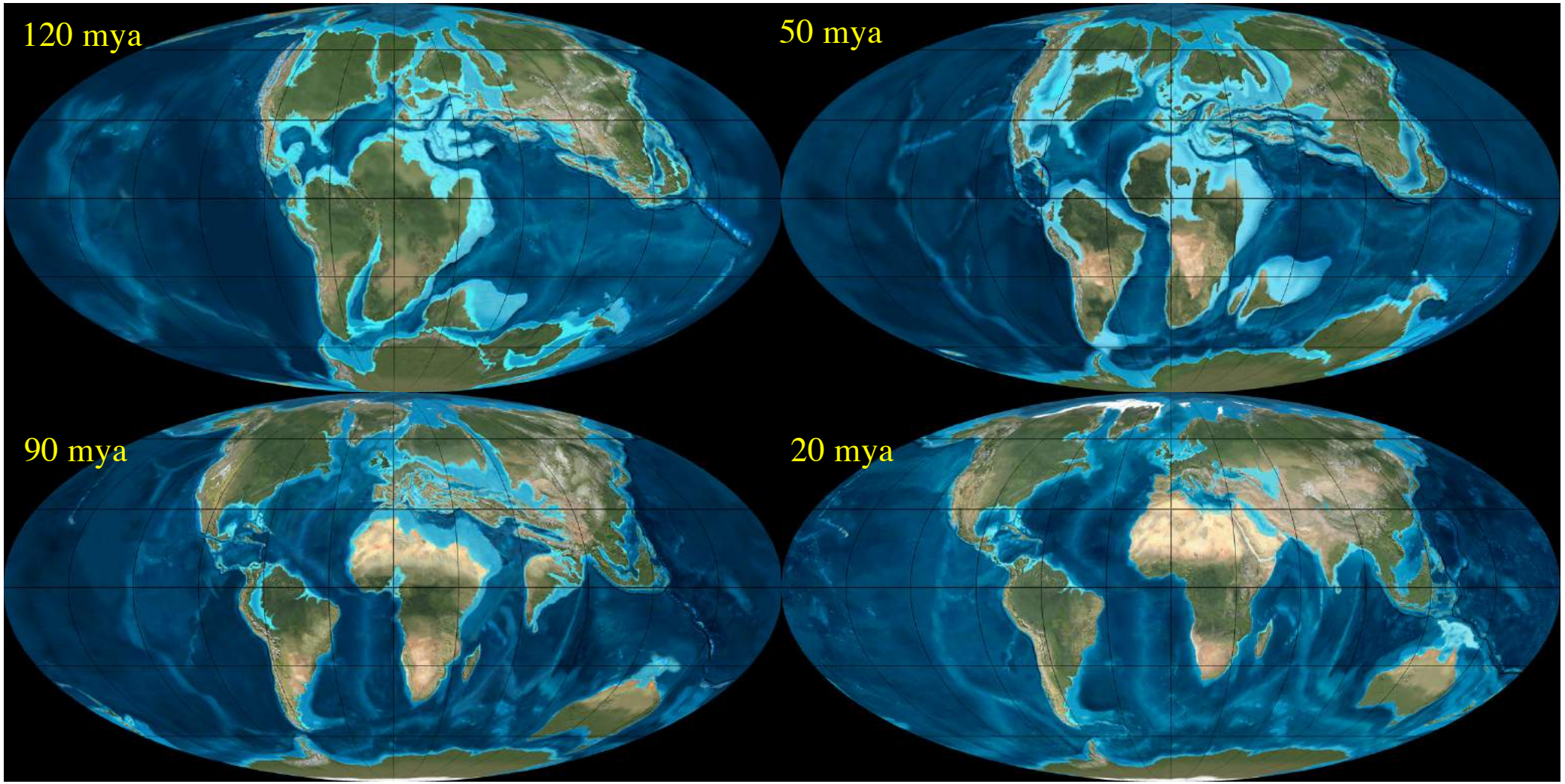


Jurassic – Cretaceous border ~ 150 million years ago

Vicariance vs. Dispersal?

Temperate Gondwanan disjuncts – vicariance and/or dispersal

Timing of organism divergence vs. timing of geological divergence critical

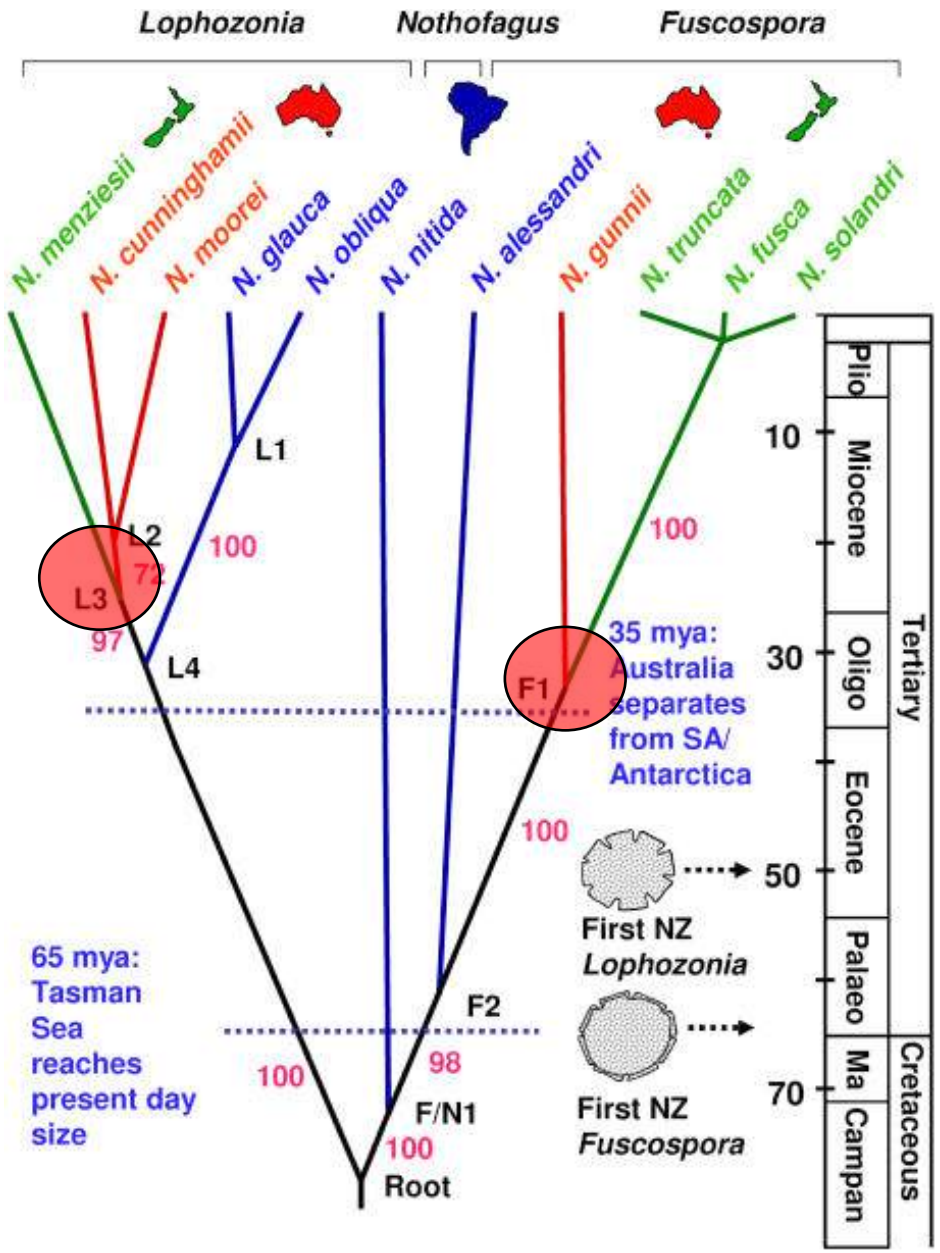


Southern Hemisphere Temperate Flora

southern beeches? –

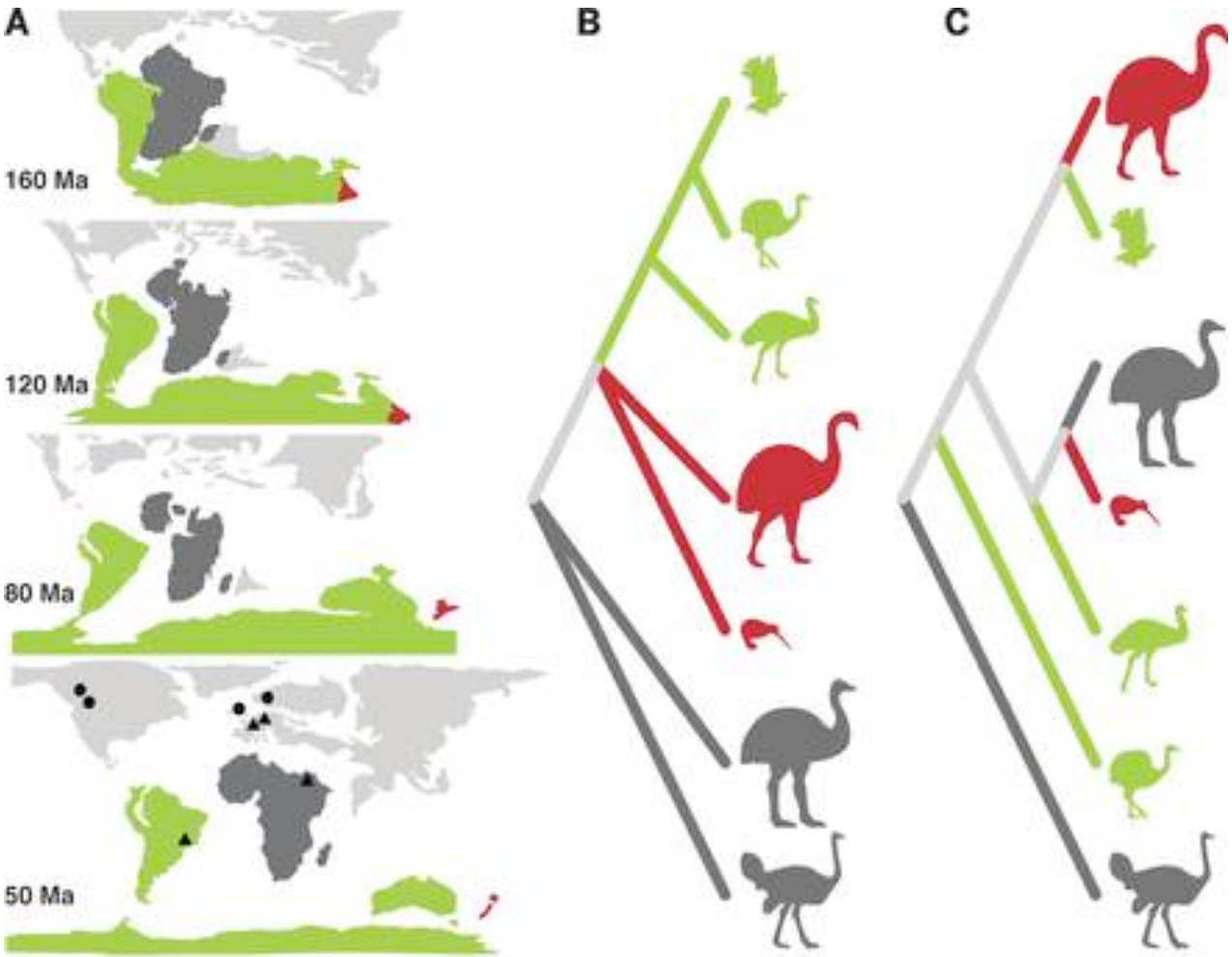
vicariance and a lot of dispersals

Australia <—> New Zealand dispersals



Southern Hemisphere Temperate Fauna

ratites – flightless birds? vicariance and a lot of dispersals



A. Geological connections

B. Geological story

C. Mitochondrial story (different story)

Science 2014 Mitchell et al.

Southern Hemisphere Temperate Fauna

ratites – flightless birds

Ancient DNA reveals elephant birds and kiwi are sister taxa and clarifies ratite bird evolution

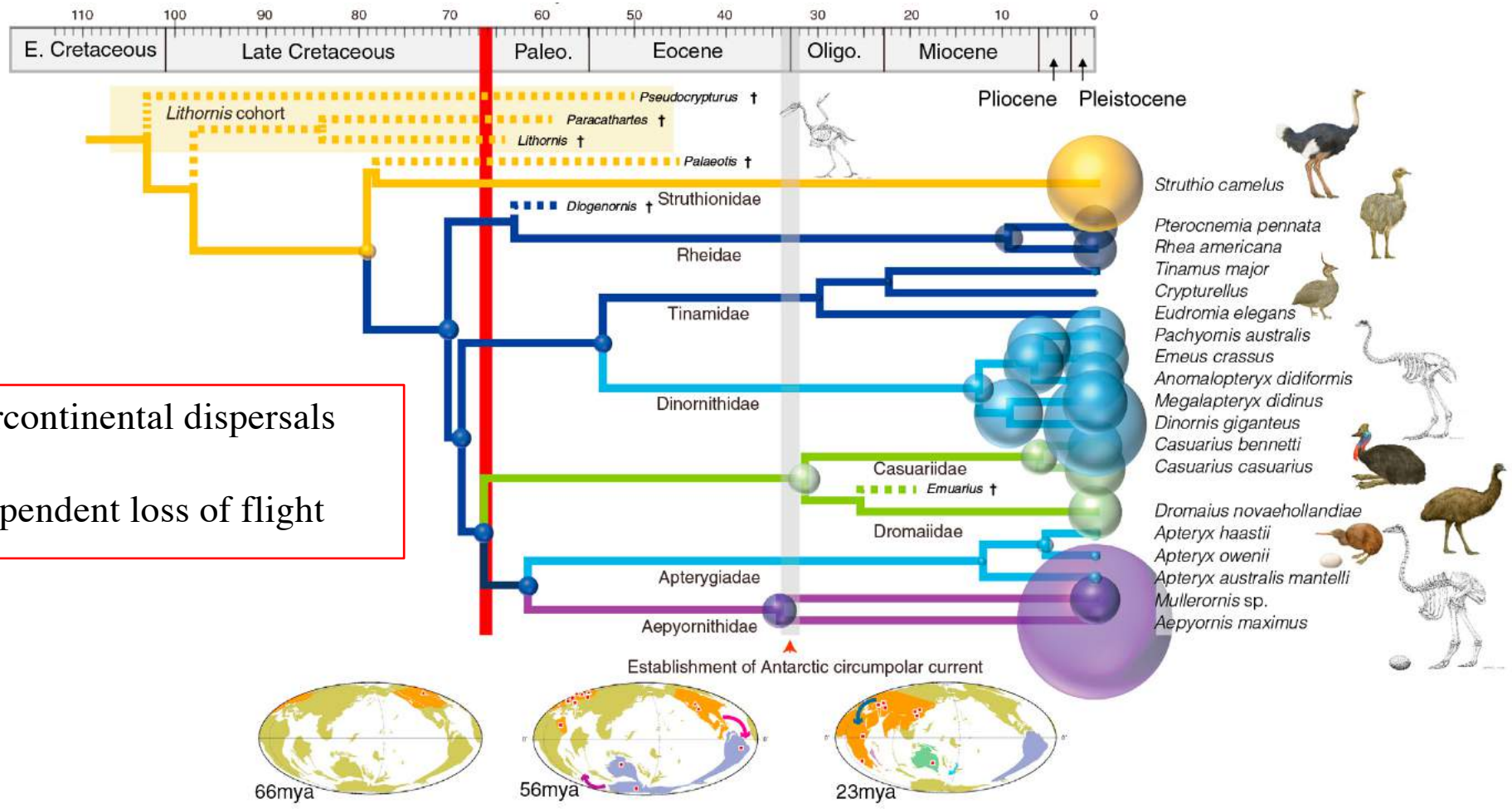
Kieren J. Mitchell,[1] Bastien Llamas,[1] Julien Soubrier,[1] Nicolas J. Rawlence,[1]* Trevor H. Worthy,[2] Jamie Wood,[3] Michael S. Y. Lee,[1,4] Alan Cooper[1]†

The evolution of the ratite birds has been widely attributed to vicariant speciation, driven by the Cretaceous breakup of the supercontinent Gondwana. The early isolation of Africa and Madagascar implies that the ostrich and extinct Madagascan elephant birds (Aepyornithidae) should be the oldest ratite lineages. We sequenced the mitochondrial genomes of two elephant birds and performed phylogenetic analyses, which revealed that these birds are the closest relatives of the New Zealand kiwi and are distant from the basal ratite lineage of ostriches. This unexpected result strongly contradicts continental vicariance and instead supports flighted dispersal in all major ratite lineages. We suggest that convergence toward gigantism and flightlessness was facilitated by early Tertiary expansion into the diurnal herbivory niche after the extinction of the dinosaurs.

Southern Hemisphere Temperate Fauna

ratites – flightless birds

Yonezawa et al. (2017) Phylogenomics and morphology of extinct paleognaths reveal the origin and evolution of the ratites. *Current Biology*



intercontinental dispersals

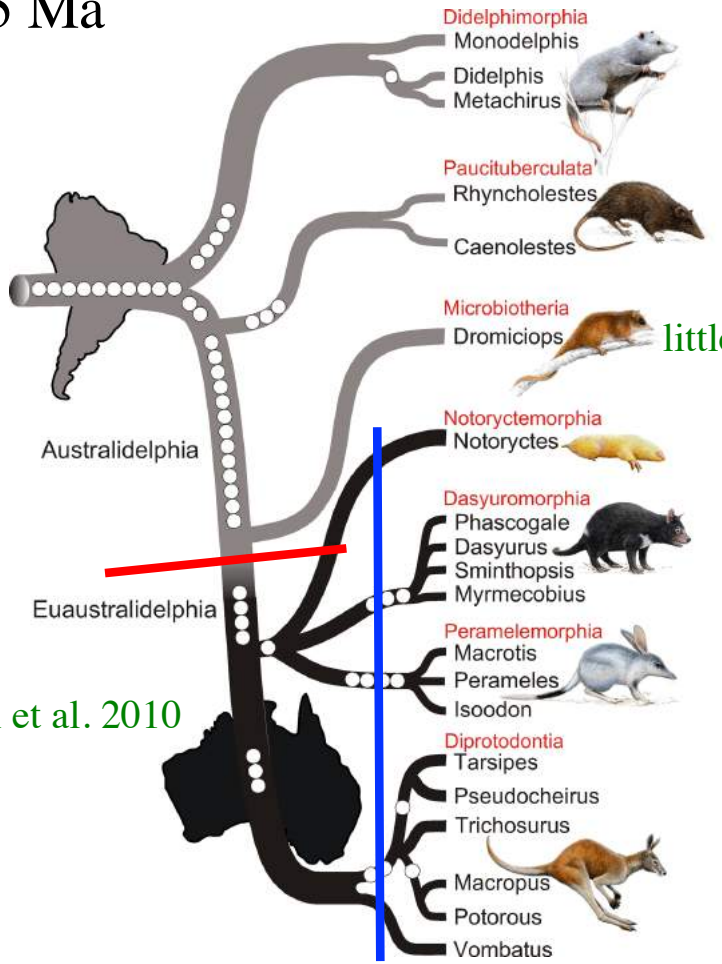
independent loss of flight

Figure 4. Palaeognathae Genomic Time Tree and Body Size

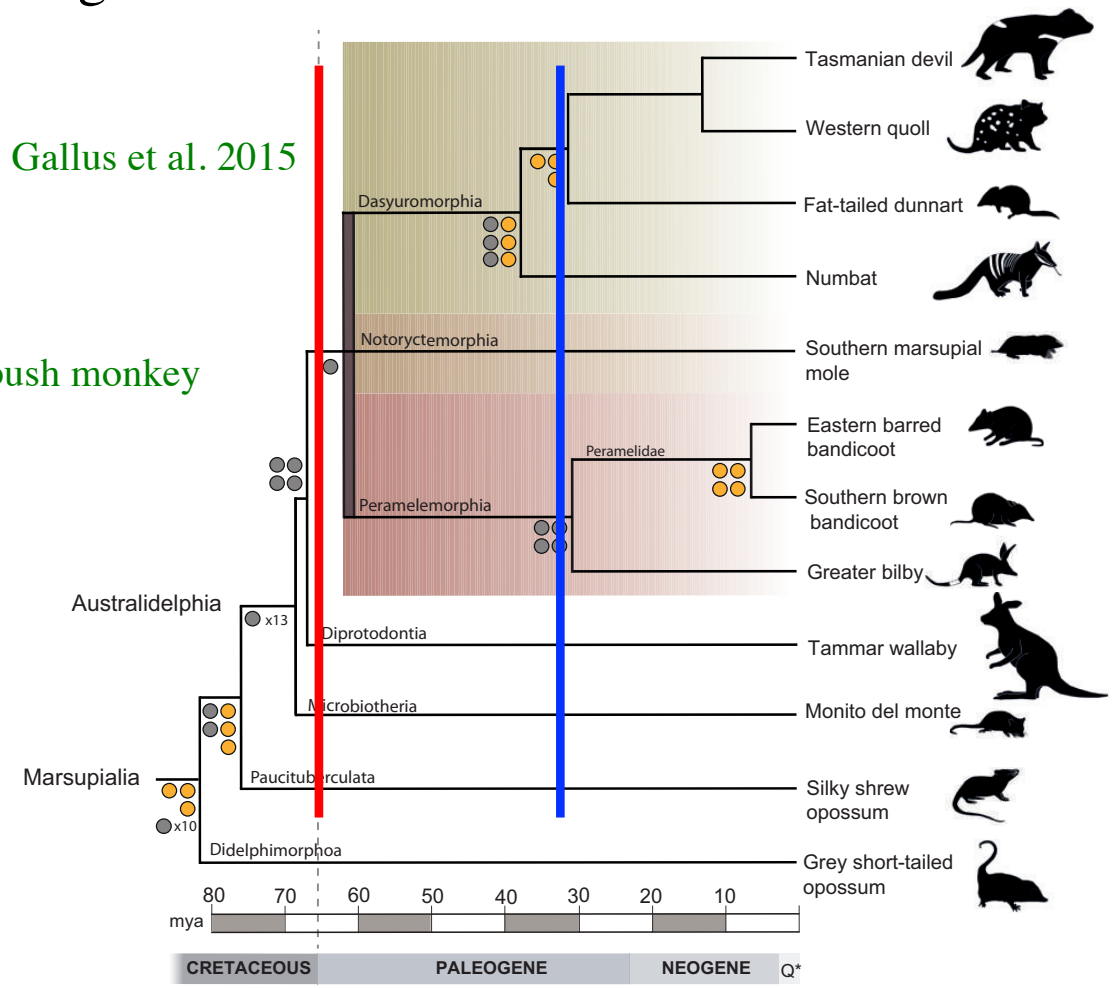
Southern Hemisphere Temperate Fauna

Dromiciops

Tracking marsupial evolution using genomic data -
marsupial and placental mammals diverged in the Late Cretaceous
~85 Ma



Nilsson et al. 2010



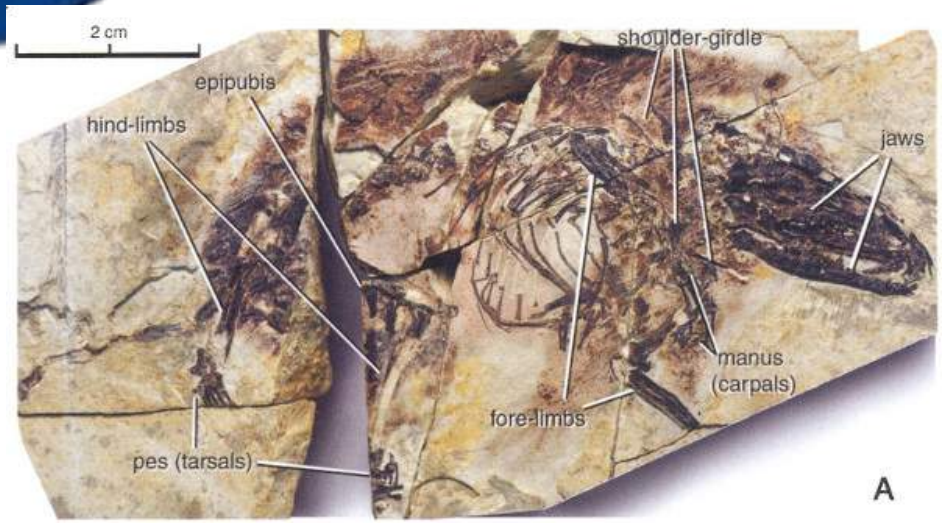
marsupial disjunction between South America and Australia vicariance or dispersal?

marsupial migration via Antarctica by KT event, adaptive radiation, and then later vicariance

Vicariance vs. Dispersal?

Fossils of both marsupials and placental mammals found in Antarctica

Fossil marsupial (Eocene 40 Ma)



Why did marsupials but NOT placental mammals migrate on to Australia?

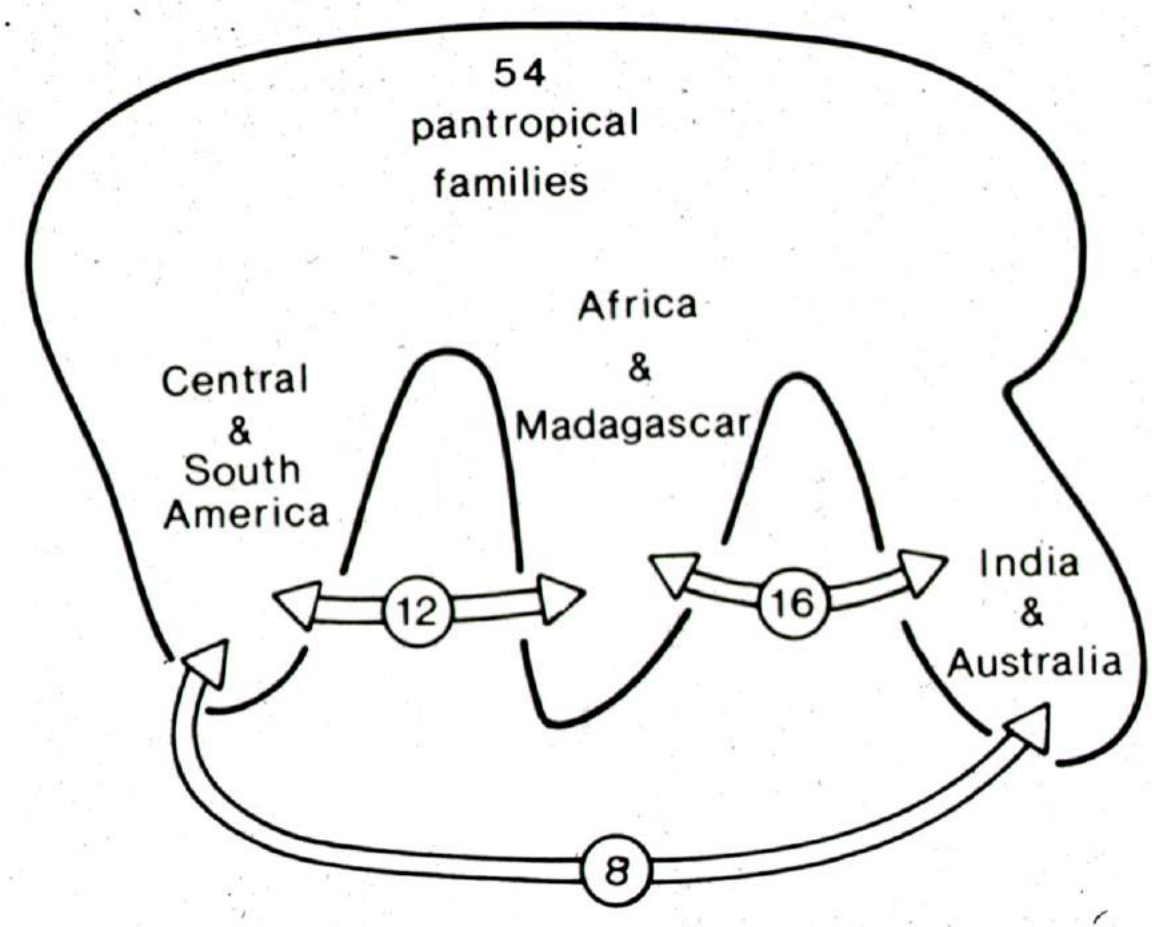
Relationships of Floras (& Faunas)

Knowledge of earth and organism histories now permit closer examination of relationships of disjunct floras and faunas.

- Southern Hemisphere temperate
- Southern Hemisphere tropics
- the Wallace Line
- Eastern Asian - Eastern North American temperate

Southern Hemisphere Tropical Flora

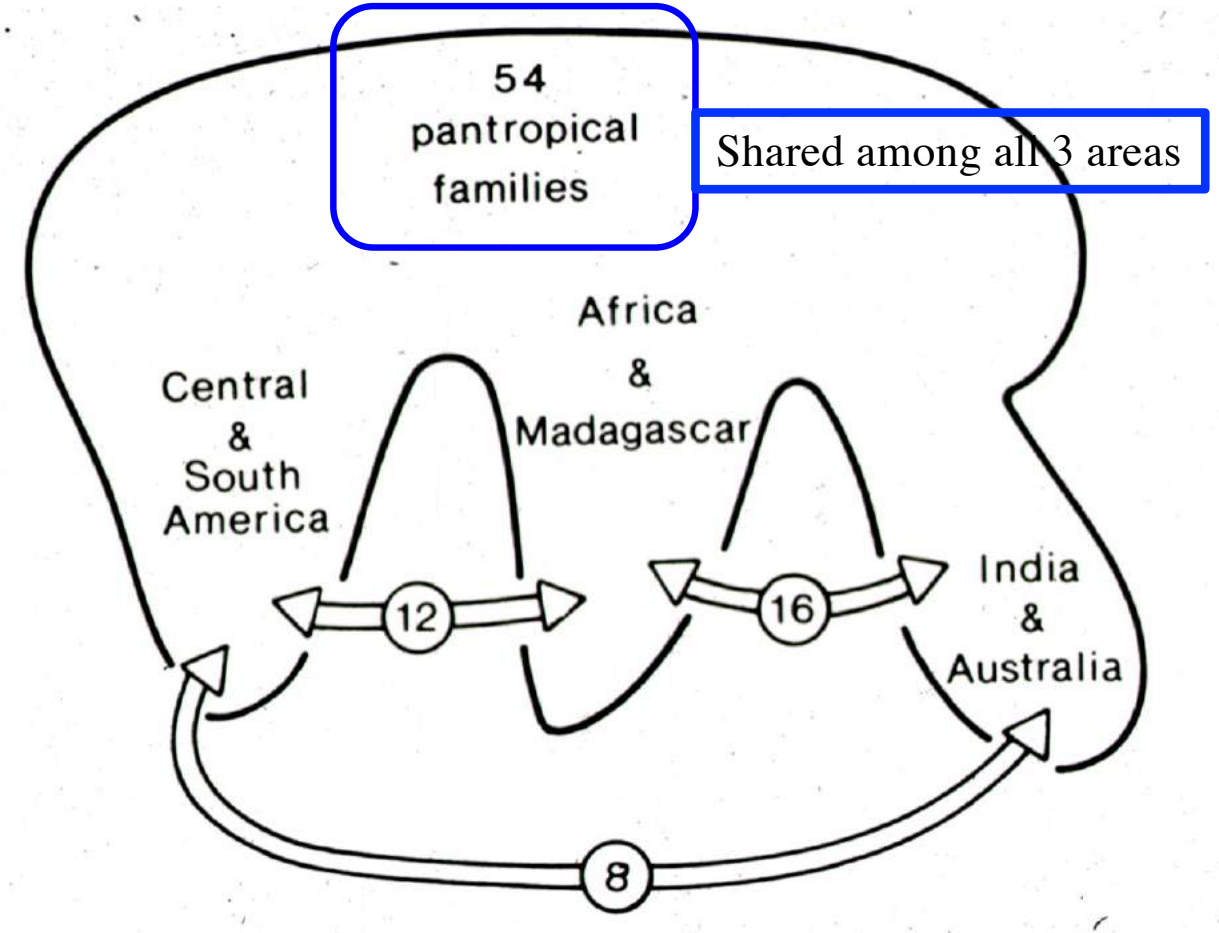
The floristic relationships among the three southern hemisphere continents are quite different when one examines the tropical floras.



Numbers of shared families between the three tropical floristic regions

Southern Hemisphere Tropical Flora

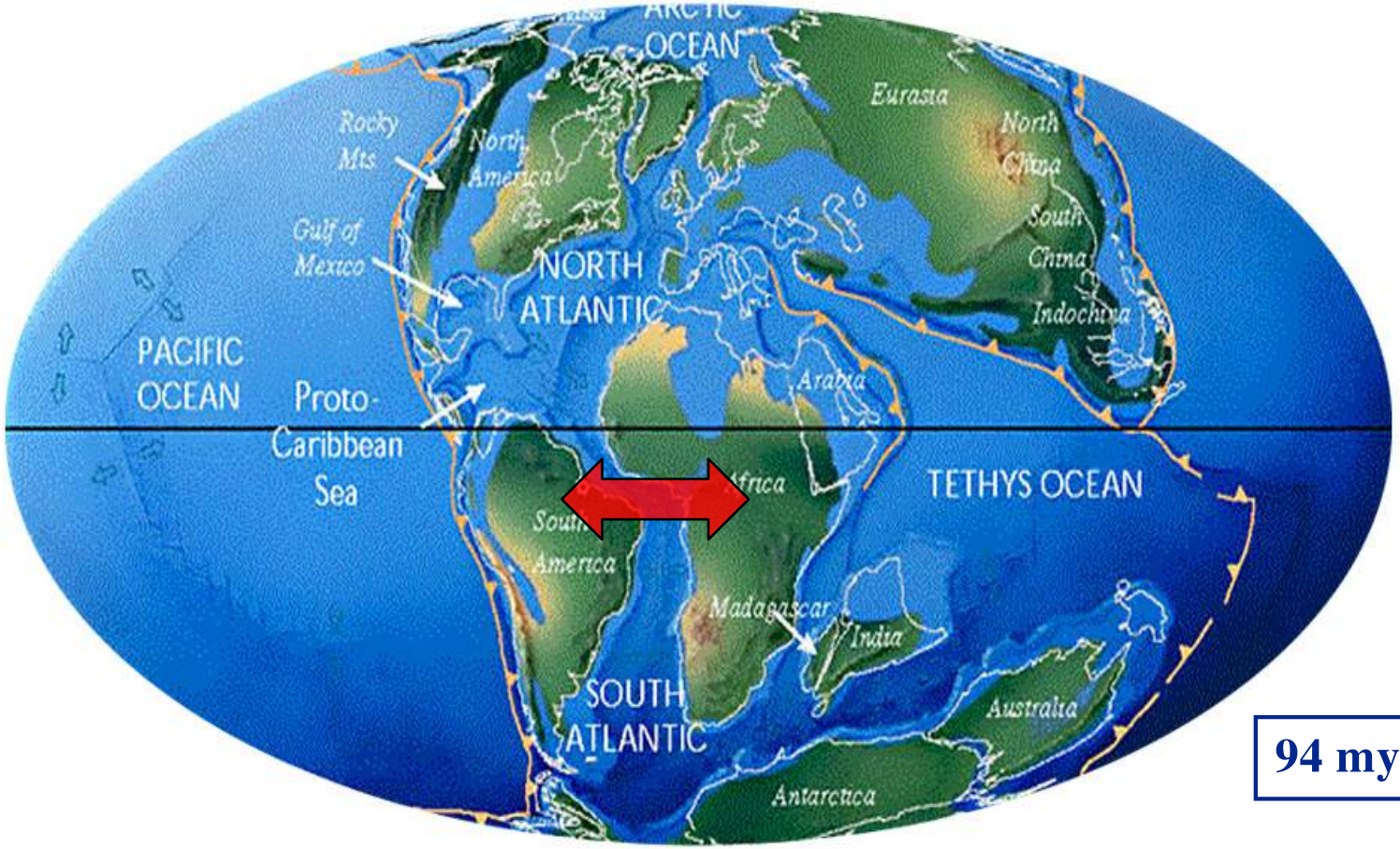
First point is that there are a large number of pantropical families — indicating tropical connections throughout the Cretaceous



Numbers of shared families between the three tropical floristic regions

Southern Hemisphere Tropical Flora

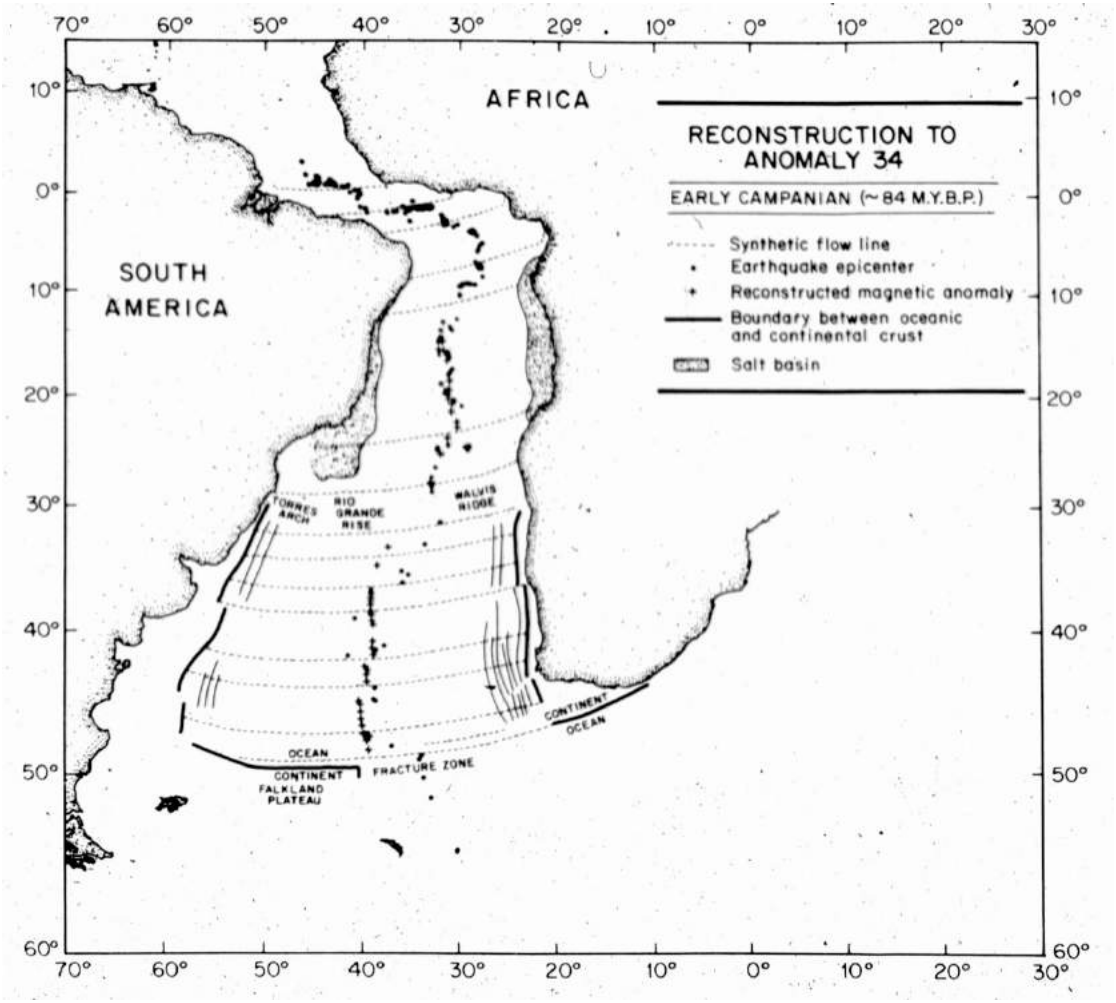
Gondwanan separation began near the early Cretaceous (135 mya), but there was still considerable tropical connections for another 40 my



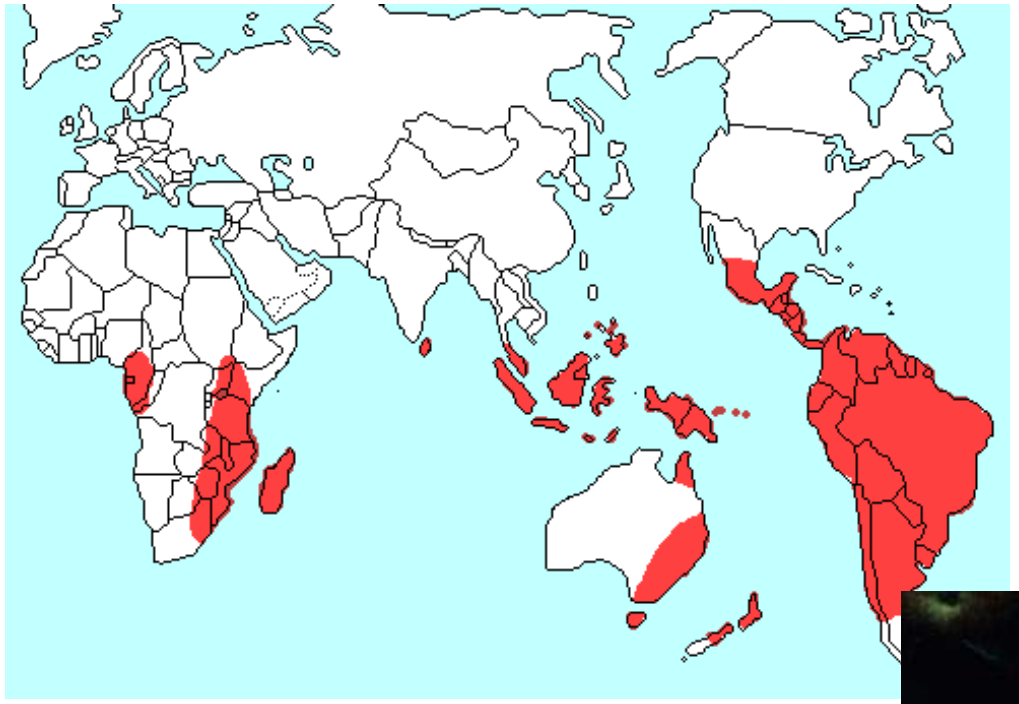
94 mya

Southern Hemisphere Tropical Flora

For example, tropical America and Africa were still close at around 84 mya (late-Cretaceous) even though temperate regions had separated 30+ my earlier



Southern Hemisphere Tropical Flora



Distribution of Monimiaceae – an early-diverging angiosperm family

Flowering plants are first seen at the earliest Cretaceous (~130Mya), and many major lineages are already seen at 90 mya

Thus, early ("primitive") families are often pantropical in distribution

Siparuna

Southern Hemisphere Tropical Flora

Distribution of *Gyrocarpus* - a genus from the early-diverging angiosperm family Hernandiaceae

Flowering plants are first seen at the earliest Cretaceous (~130Mya), and many major lineages are already seen at 90 mya

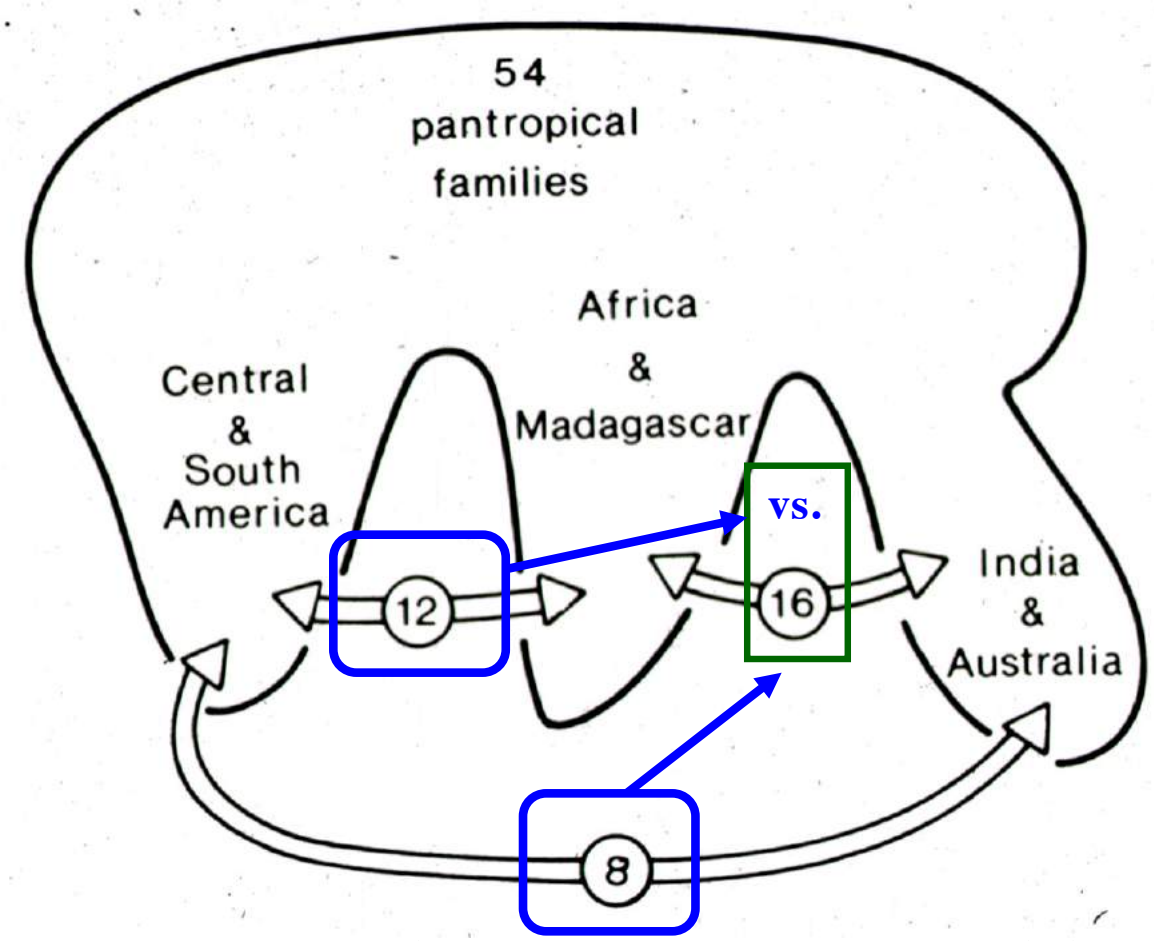
Thus, early ("primitive") families are often pantropical in distribution

. . . or even genera of these families!

Gyrocarpus jacquini
Asian tropics

Southern Hemisphere Tropical Flora

Second, Africa is not the "odd continent out" — in fact, it appears that South America seems less related in its tropical flora to either Africa or AustralAsia.

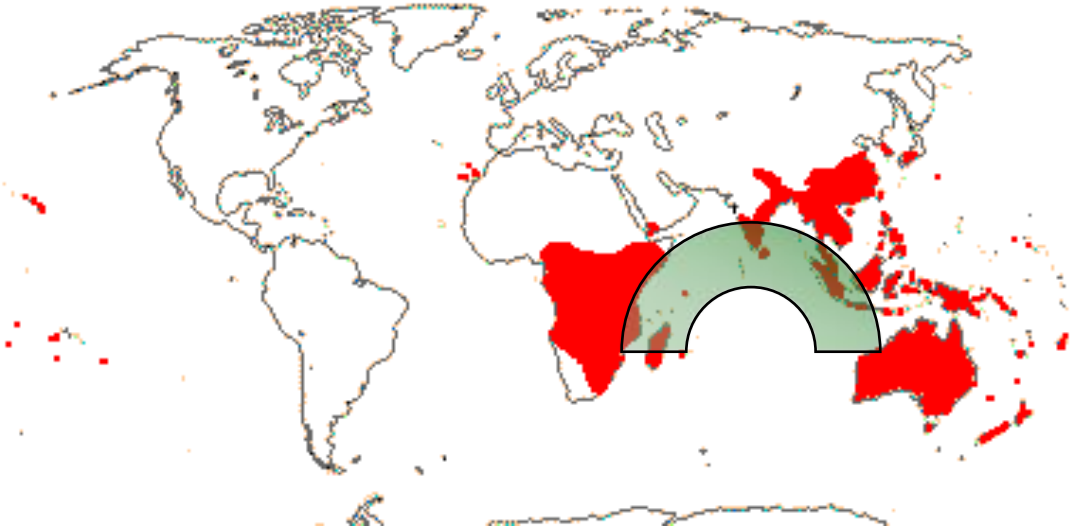


Numbers of shared families between the three tropical floristic regions

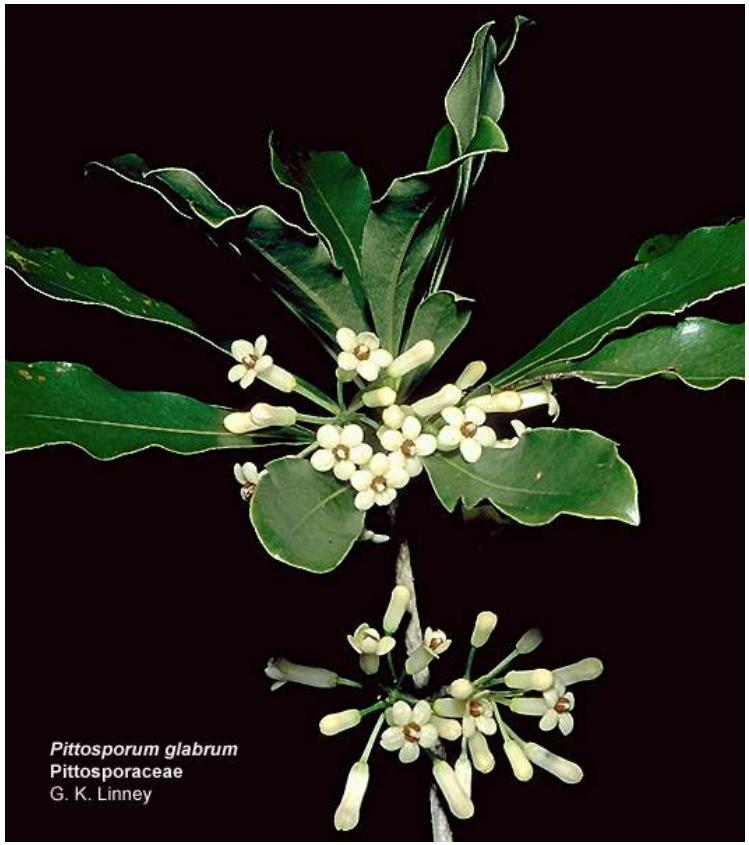
African - Australasian Distributions

Many families show the African - Australasian distribution pattern. Why?

1. A relatively continuous tropical land arc exists across the northern Indian Ocean and through the Malay Archipelago - assists migration



Distribution of Pittosporaceae



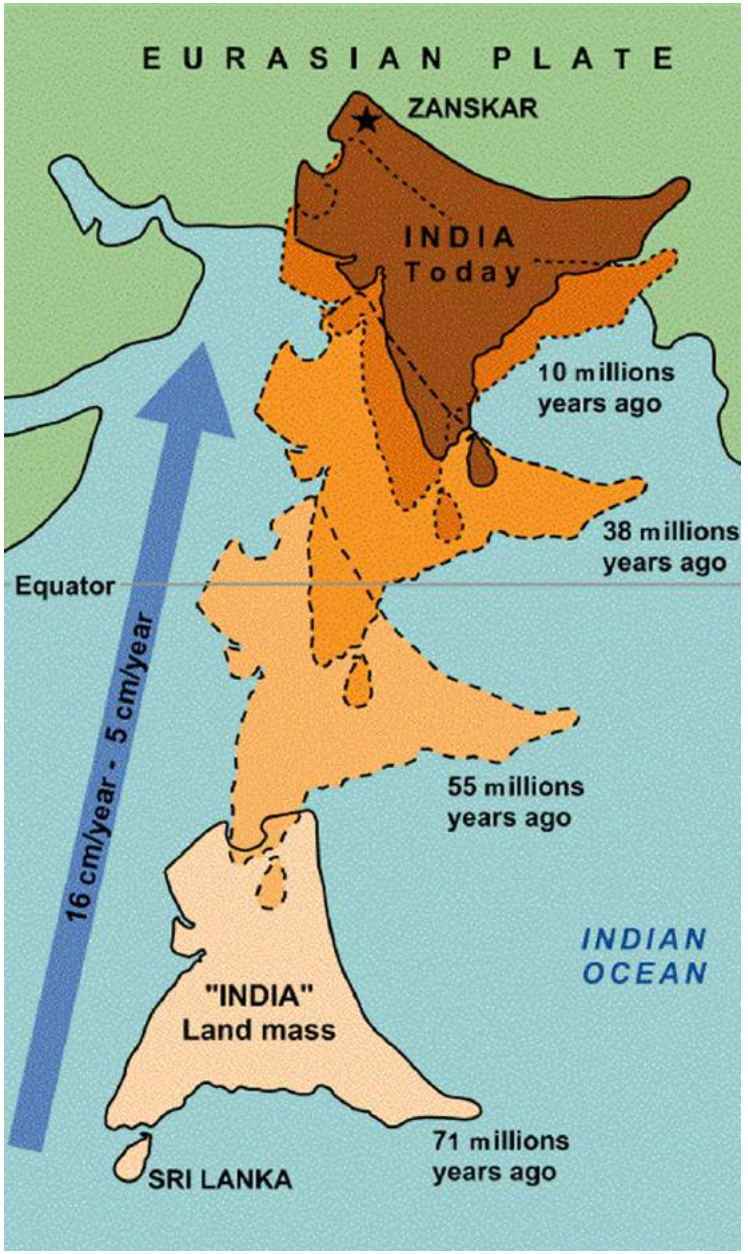
African - Australasian Distributions

Many families show the African - Australasian distribution pattern. Why?

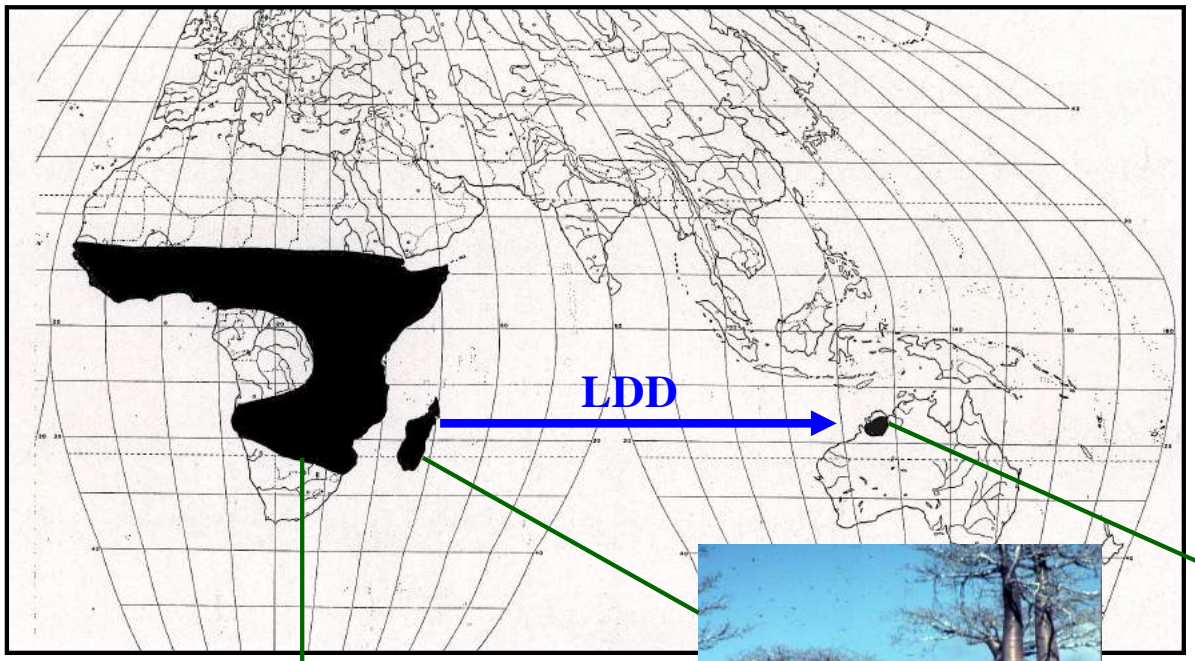
1. A relatively continuous tropical land arc exists across the northern Indian Ocean and through the Malay Archipelago - assists migration

2. India, Africa, and Australia all rafted up to make contact with the Eurasian plate at different times - facilitates mixing

3. These factors appear to have set the conditions for Long Distance Dispersal



African - Australasian Distributions



The baobab (*Adansonia* - Malvaceae) disjunct pattern has been shown to be due to long distance dispersal

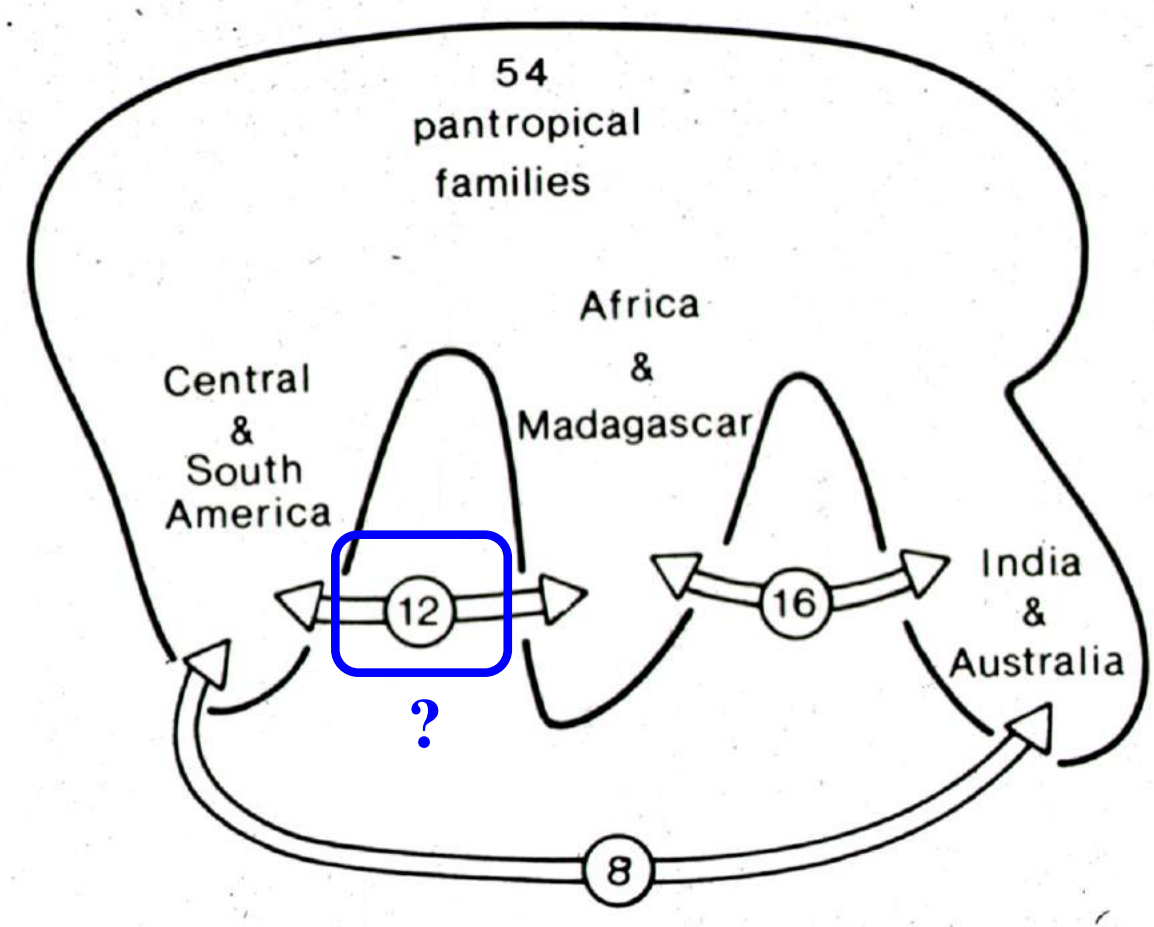
Adansonia digitata

Adansonia grandidieri

Adansonia gregorii

Southern Hemisphere Tropical Flora

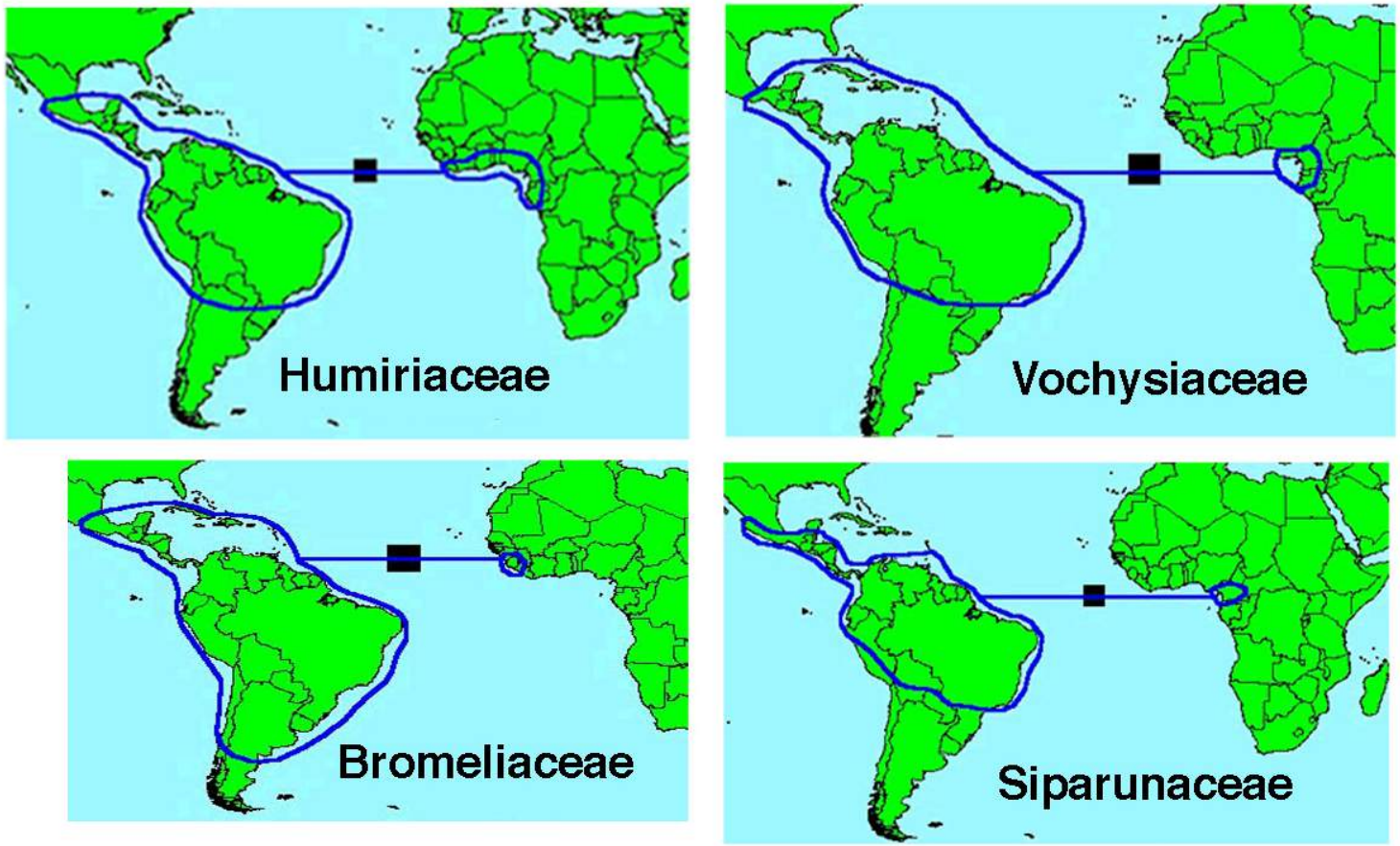
Third, 12 families shared only between South America and Africa *may not indicate shared biota . . .*



Numbers of shared families between the three tropical floristic regions

Southern Hemisphere Tropical Flora

Third, 12 families shared between South America and Africa *may not indicate shared biota . . .*

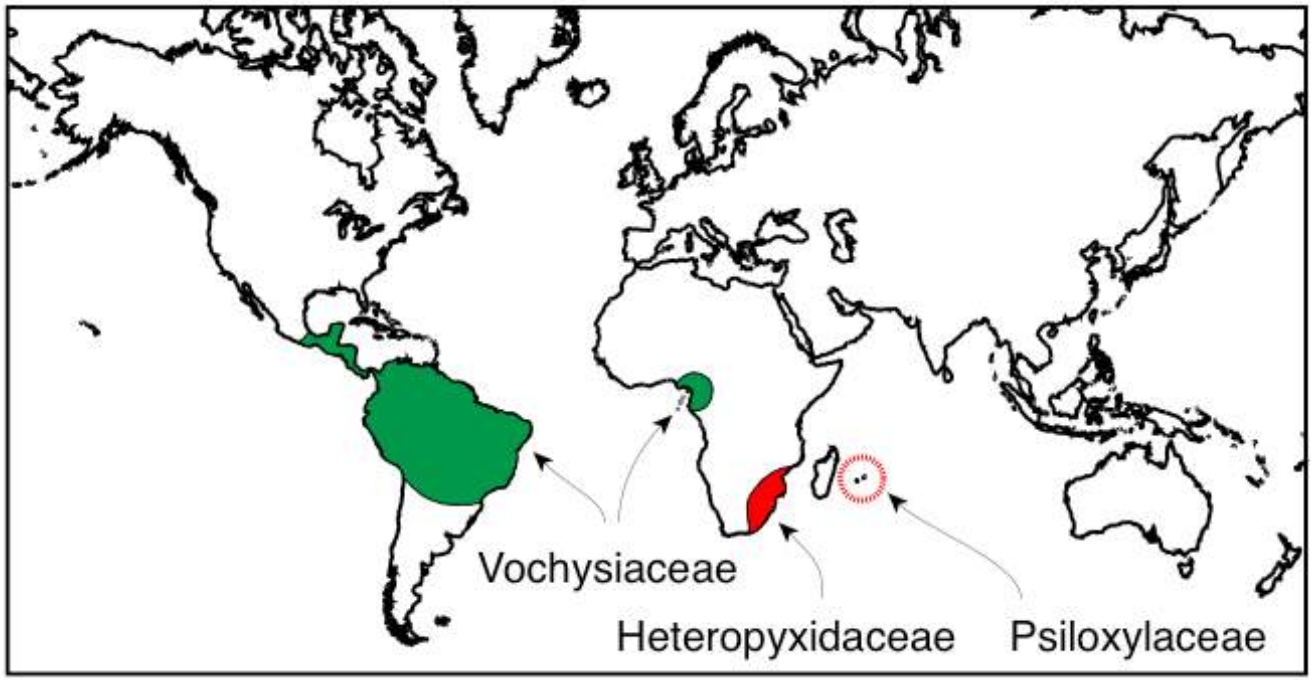


although vicariant biogeographers argue for an *ancestral biota*

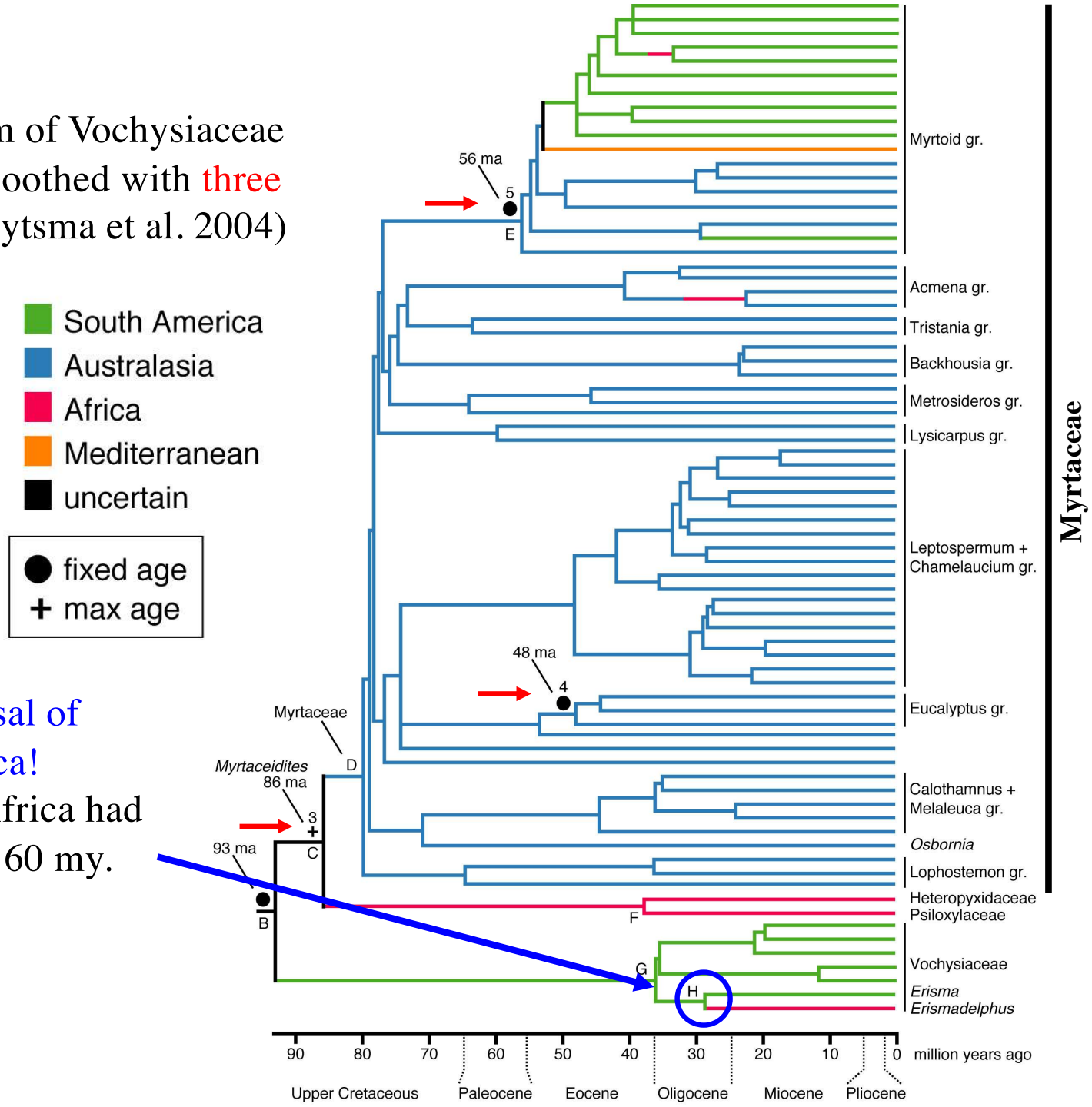
Vochysiaceae: 8 genera, 210 spp.

all American except 3 spp.

Gondwanan vicariance or dispersal?



Molecular cladogram of Vochysiaceae and relatives rate smoothed with three fossil calibrations (Sytsma et al. 2004)

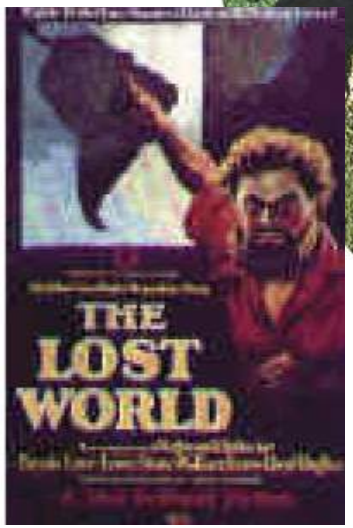


Long distance dispersal of Vochysiaceae to Africa!

South America and Africa had already separated for 60 my.

Rapateaceae - characteristic family of the Guayana Shield

Auyuan tepui



Rapateaceae - . . . and one genus from the African Man Shield

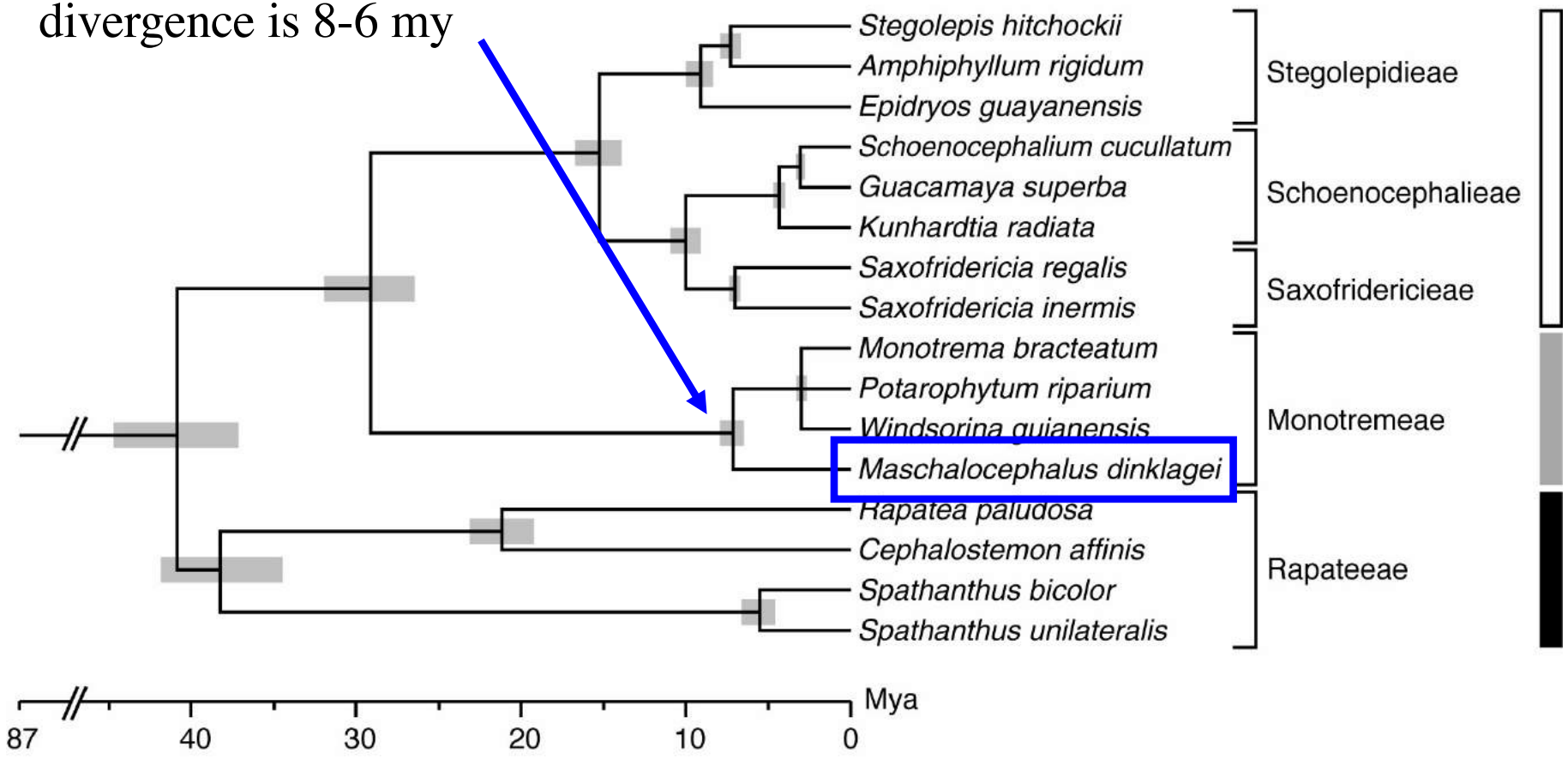
Is the African *Mascolocephalus* a vicariad with closest Guayana Shield relatives, or a product of long distance dispersal?

Rapateaceae 3-gene ML tree

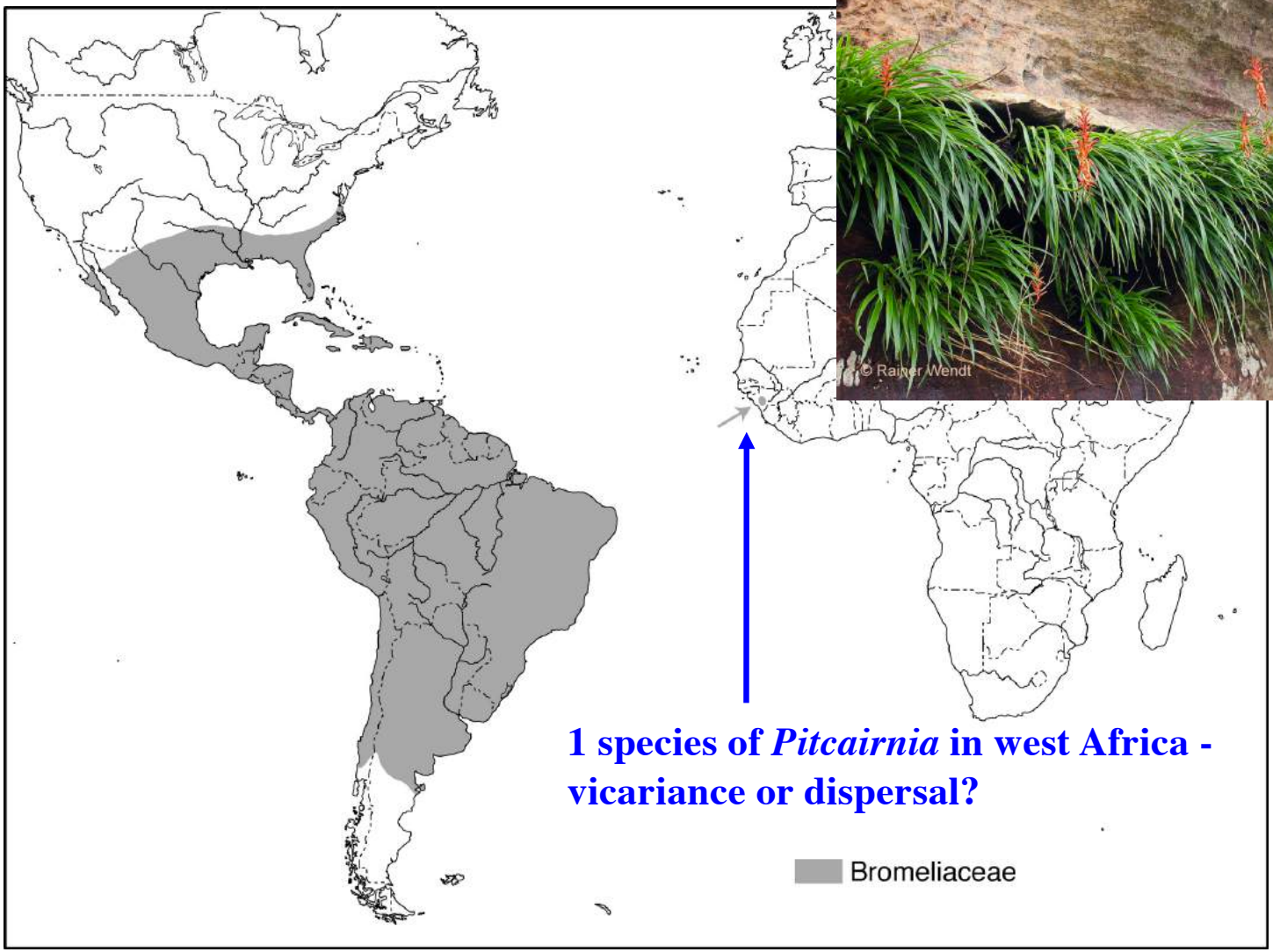
Rate smoothed with PL using 8 fossils in an across monocot survey (Givnish et al. 2004)

(error bars for age estimates)

Long distance dispersal to Africa!
African species divergence is 8-6 my



Bromeliaceae (pineapples) is an American family

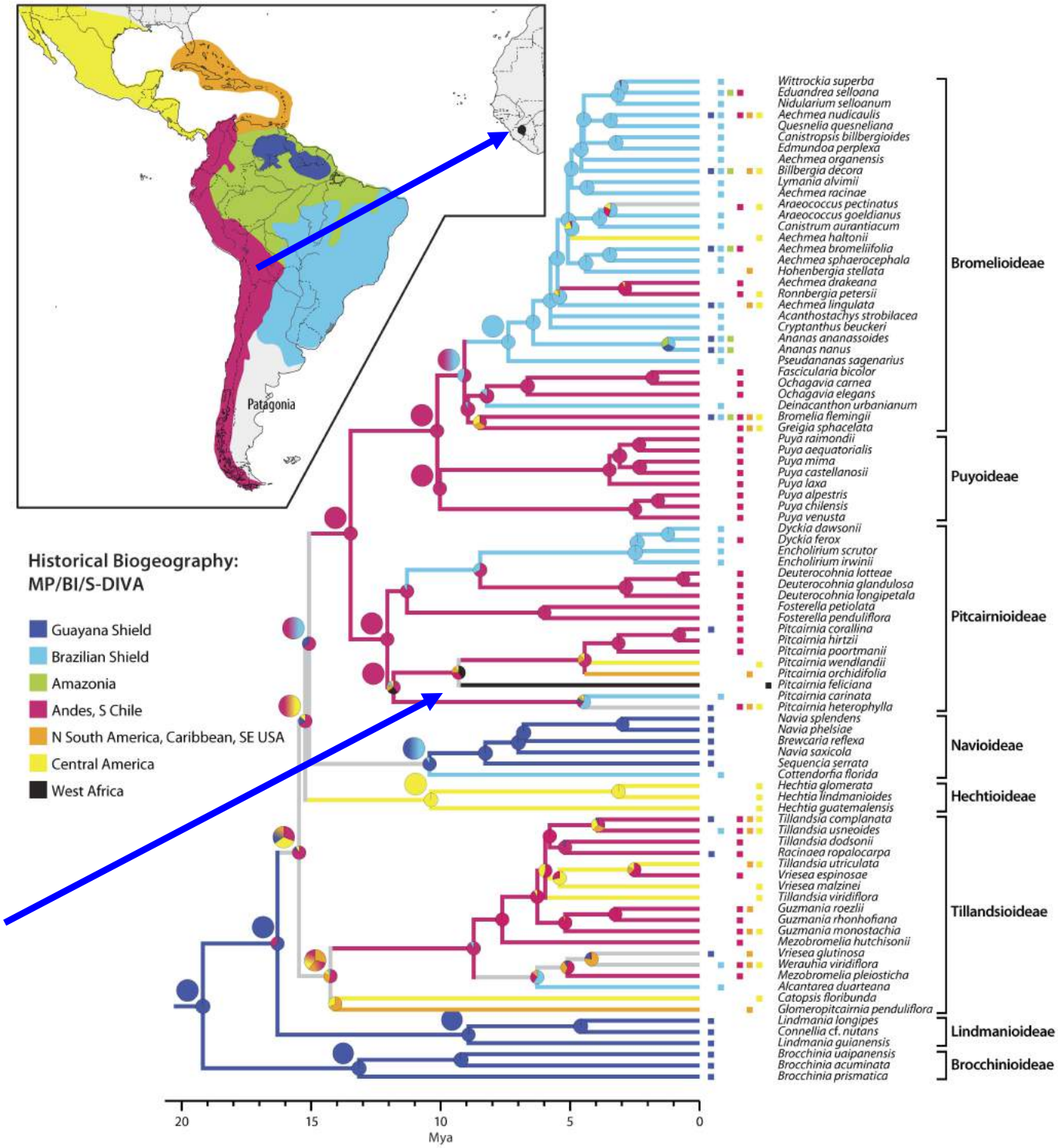


Bromeliaceae
8-gene ML tree

Rate smoothed with PL using 8 fossils in an across monocot survey (Givnish et al. 2011)

Pitcairnia feliciana derived from Andean clade

Long distance dispersal to Africa! African species divergence is <10 mya



South American - west African Disjuncts

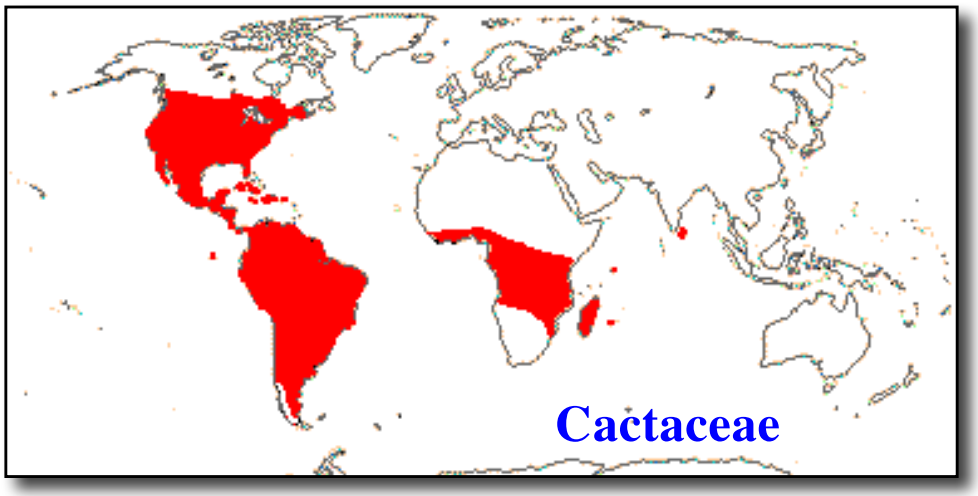
Vochysiaceae - water dispersed

Rapateaceae - bird (mud) dispersed

Bromeliaceae - ? dispersed

Cactaceae - bird dispersed

Humiriaceae - water dispersed



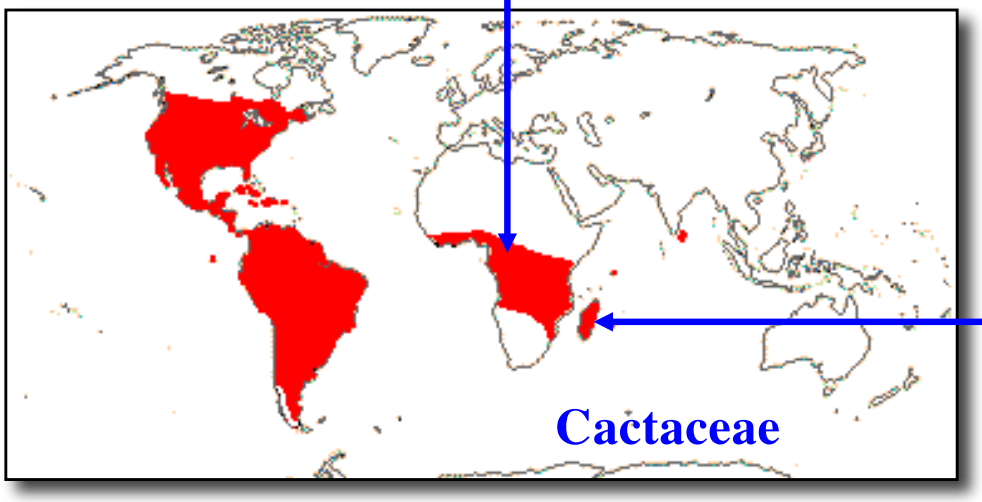
The majority of the 12 families showing this repeated pattern can not be examples of vicariance, but rather trans-oceanic dispersal at different times

South American - west African Disjuncts

Rhipsalis baccifera

Rhipsalis — fleshy fruited and bird dispersed

Rhipsalis horrida



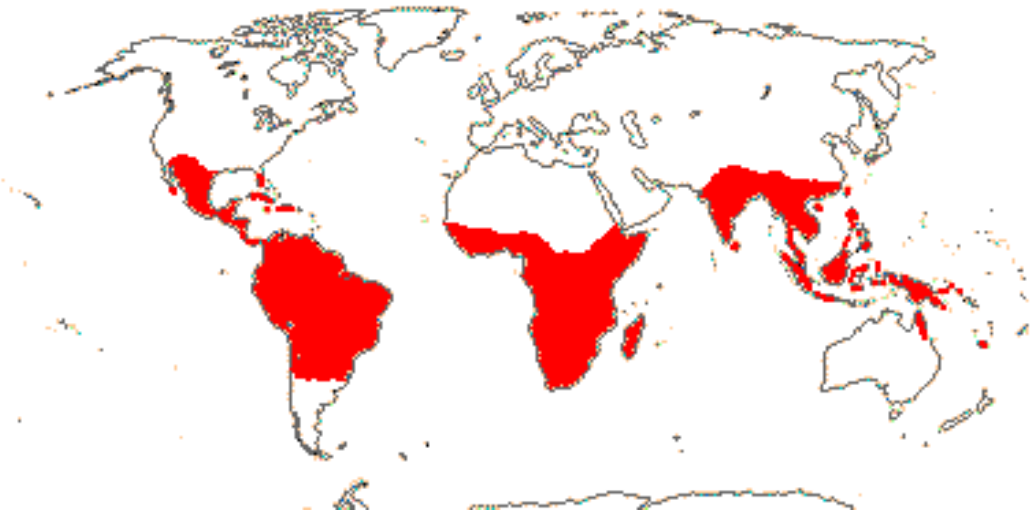
South American - west African Disjuncts

Humiriaceae
8 / 50spp

Sacoglottis with 7 species in neotropics;
1 species (*S. gabonensis*) in W. Africa

S. amazonica - water dispersed fruit

Boreotropics Hypothesis



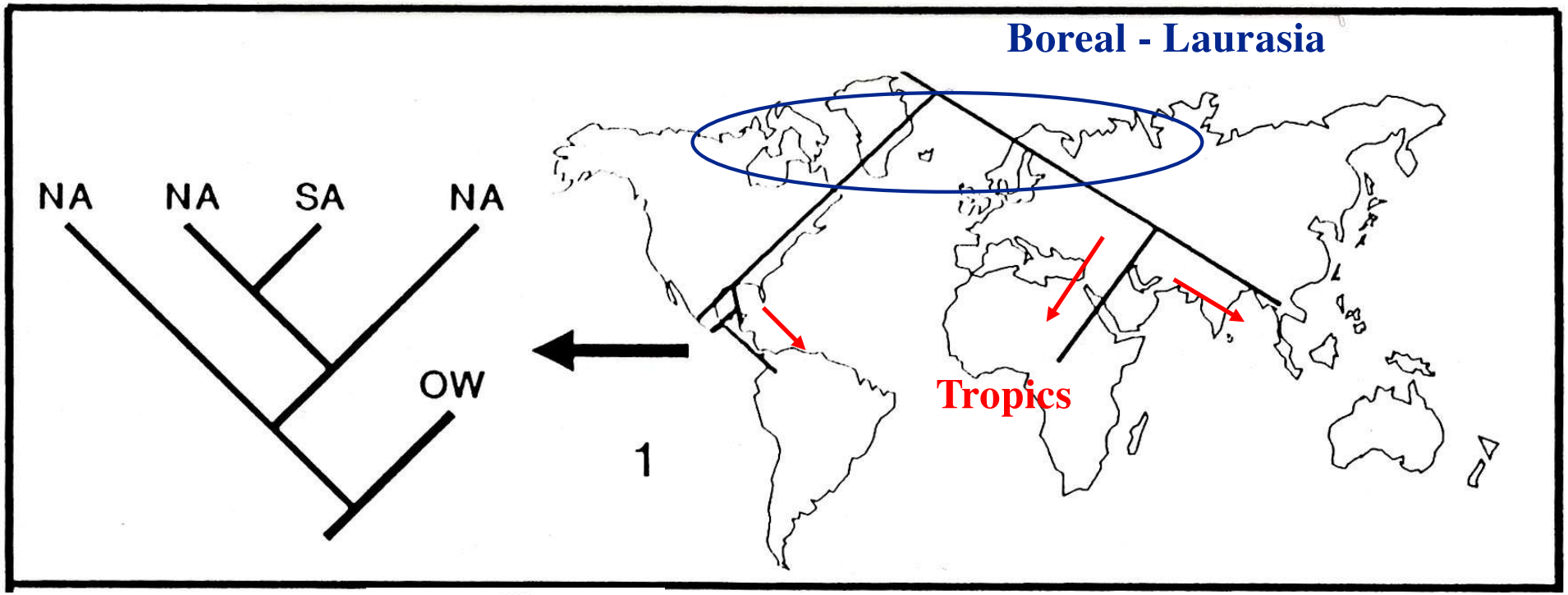
Pantropical distribution of Malpighiaceae

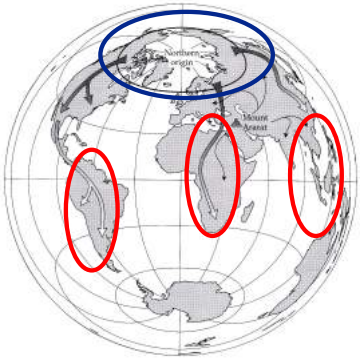
An alternative to Gondwanan vicariance or transoceanic dispersal has been proposed for several families that are largely tropical but also have northern temperate lineages

Phylogenetic analysis of these families indicate that the northern lineages are basal or primitive and not derived as previously suspected – Boreotropical hypothesis

Boreotropics Hypothesis

- these families likely originated in Laurasia (not Gondwana)
- and migrated to the tropics in two or three separate lineages

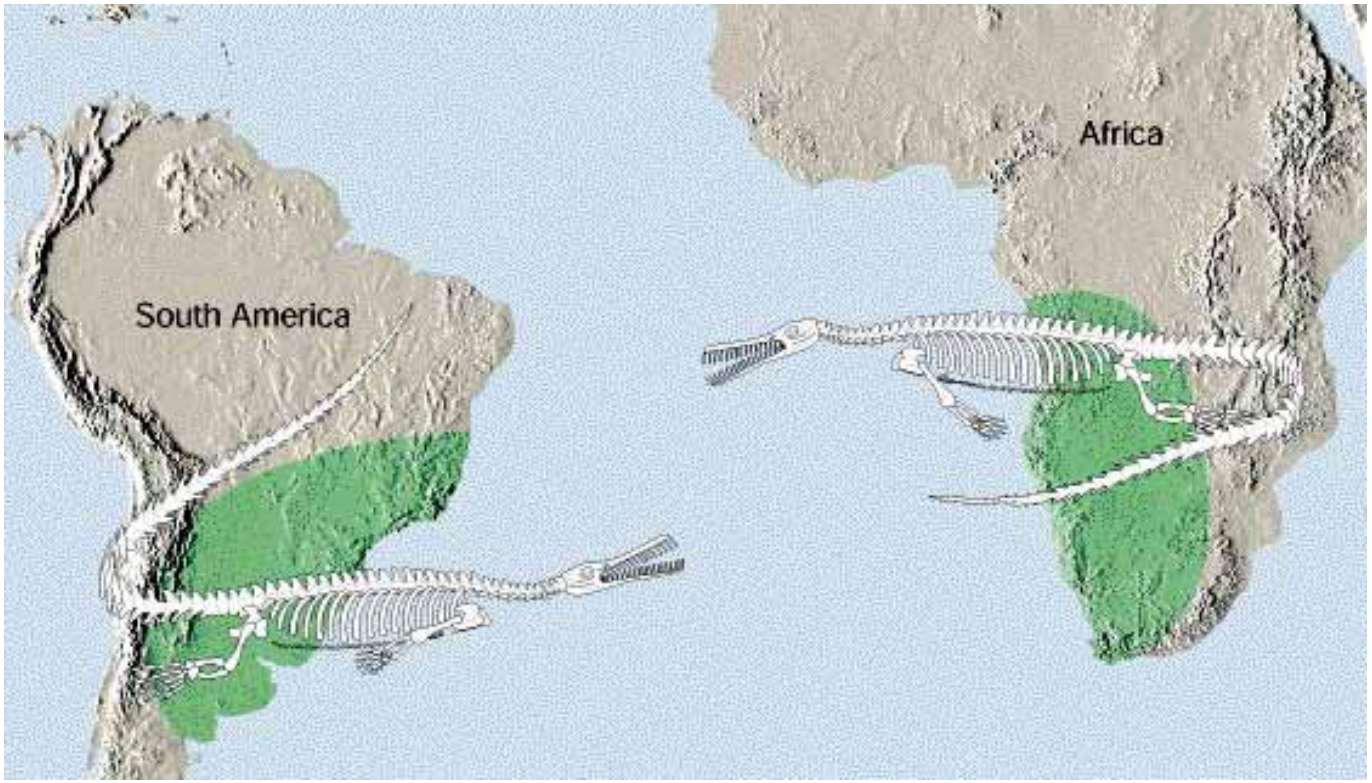




Comte de Buffon (1707–1788)

Southern Hemisphere Faunal Relationships

Does vicariance explain patterns of animal distributions? Certainly for old lineages such as Reptilia

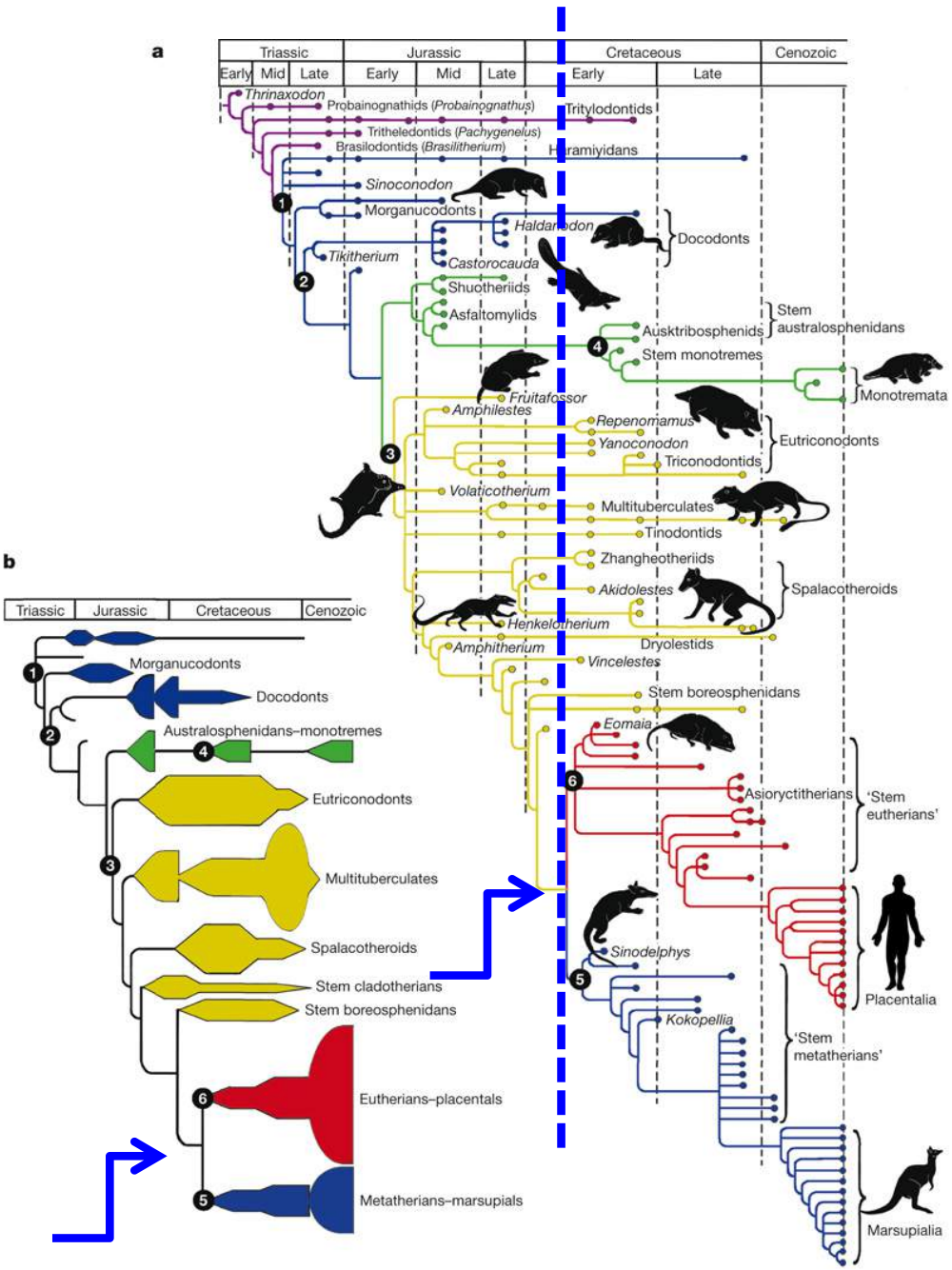


Mesosaurus - Permian freshwater reptile

Southern Hemisphere Faunal Relationships

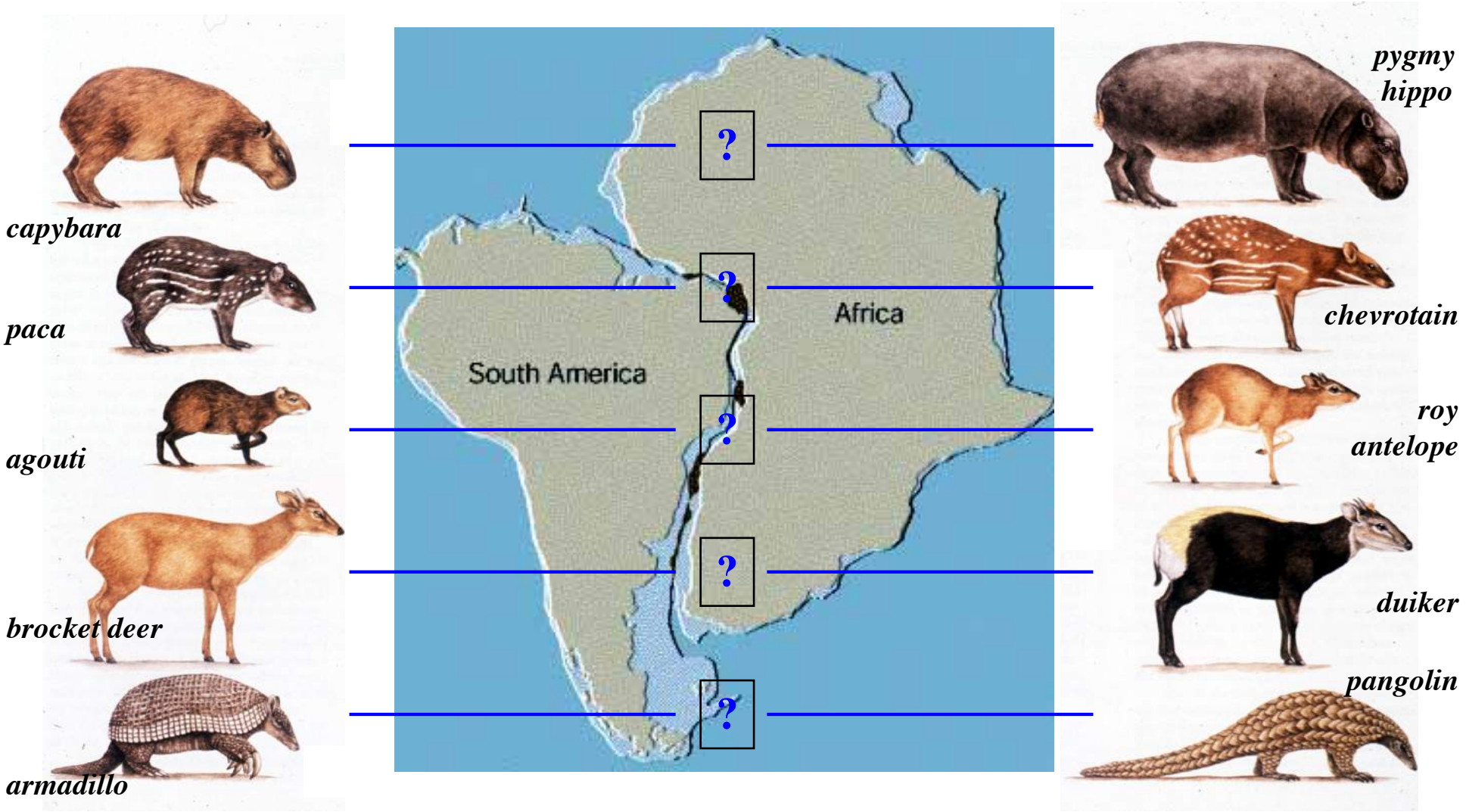
Does vicariance explain patterns of animal distributions? Certainly for old lineages such as Reptilia and mammals

Placental vs. marsupial separation in earliest Cretaceous



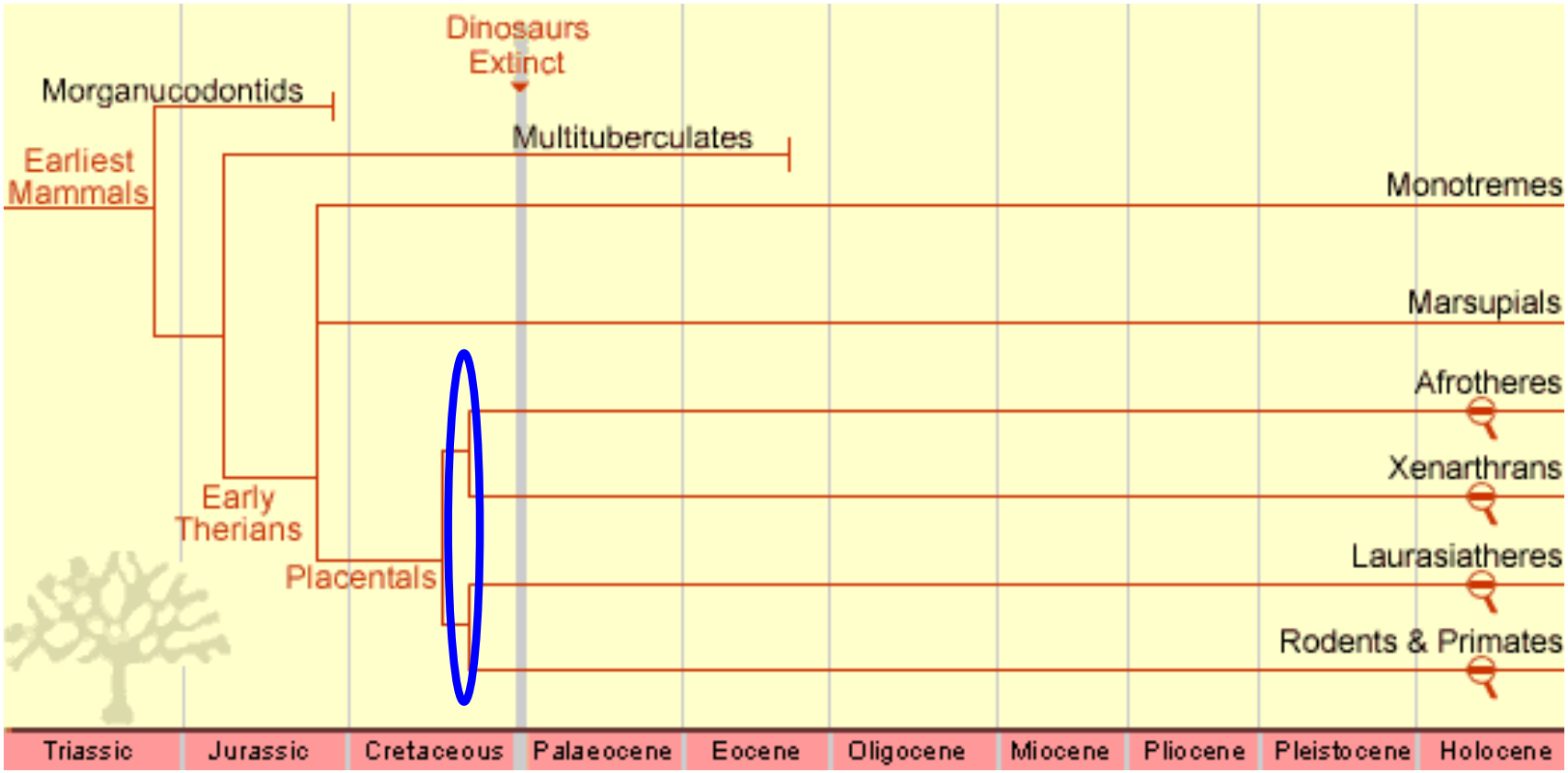
Southern Hemisphere Faunal Relationships

Does vicariance explain patterns of placental mammal distributions? Long controversy on how South American and African placentals are related.



Southern Hemisphere Faunal Relationships

Major radiations of placental mammals occurred after Gondwanan separation and split of tropical South America and Africa



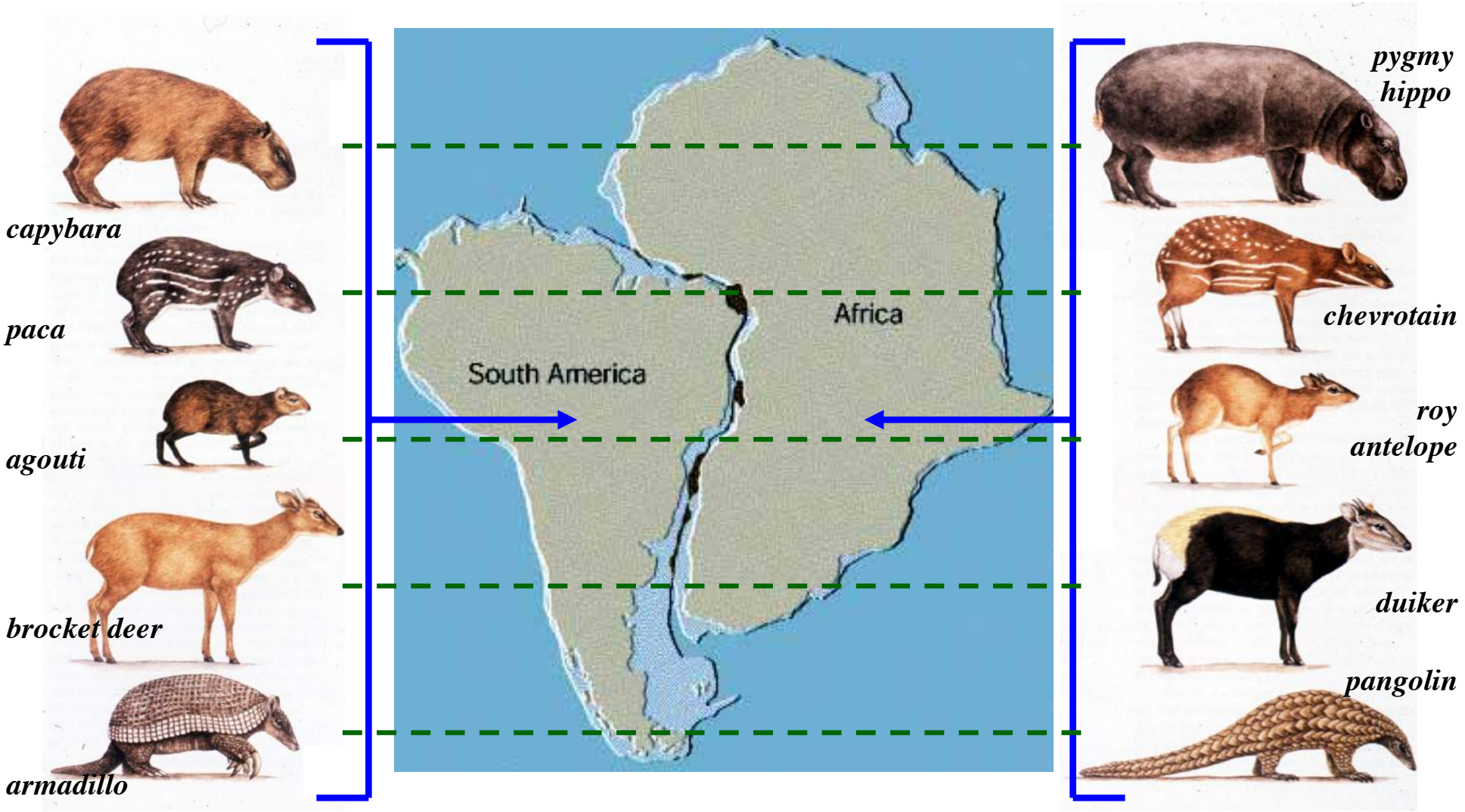
64 mya

90 mya - separation of tropical South America and Africa

135 mya - separation of Gondwana

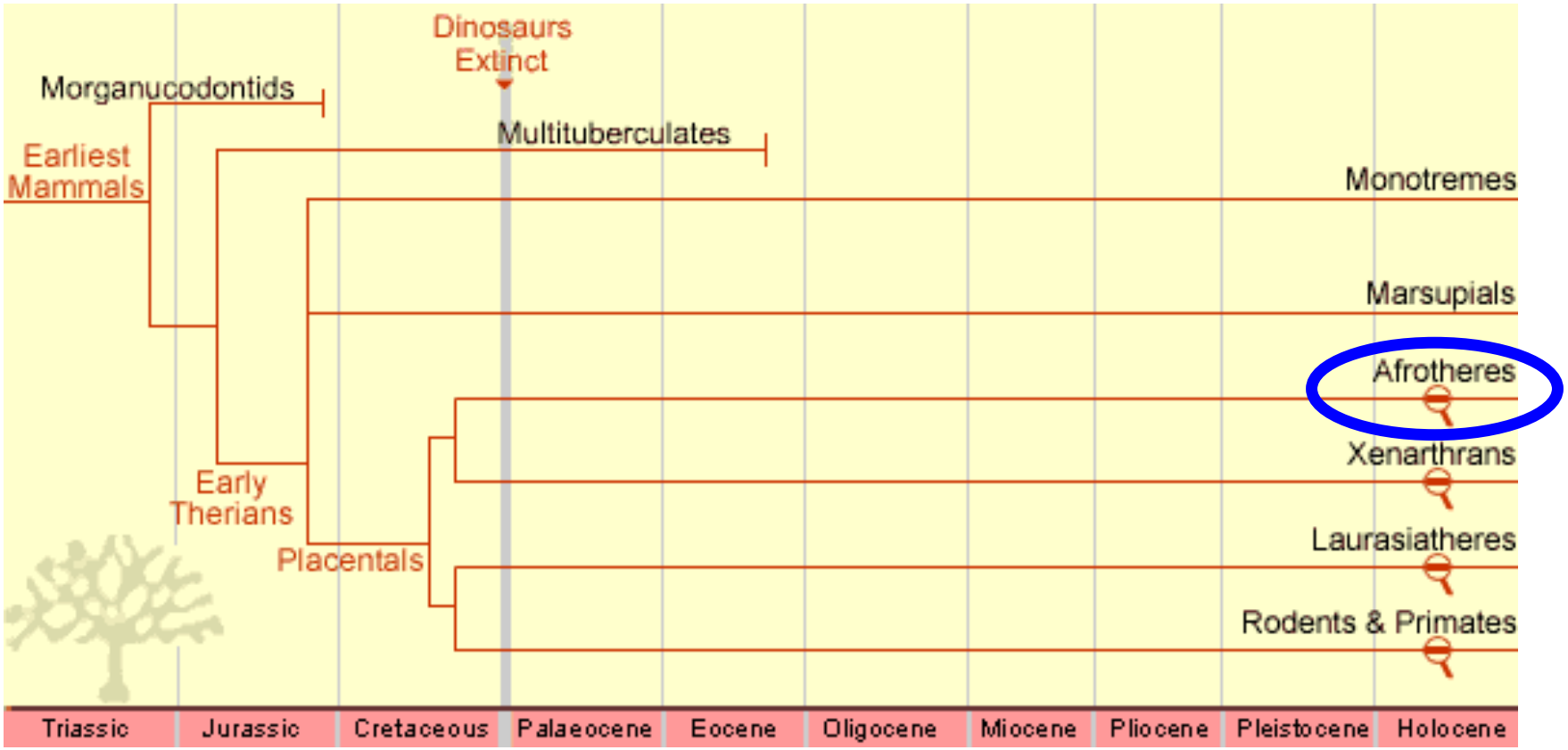
Southern Hemisphere Faunal Relationships

Relationships in placental mammals exist only within a continent and similarities between South America and Africa are a striking case of **convergence**.



Southern Hemisphere Faunal Relationships

A major surprise in the last few years using DNA sequences has been the recognition of a biogeographically defined lineage of African mammals with no (at least initially) defining morphological features — **Afrotheria**



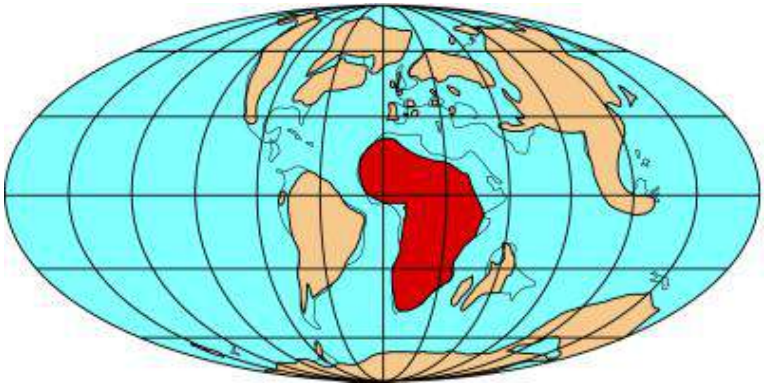
64 mya

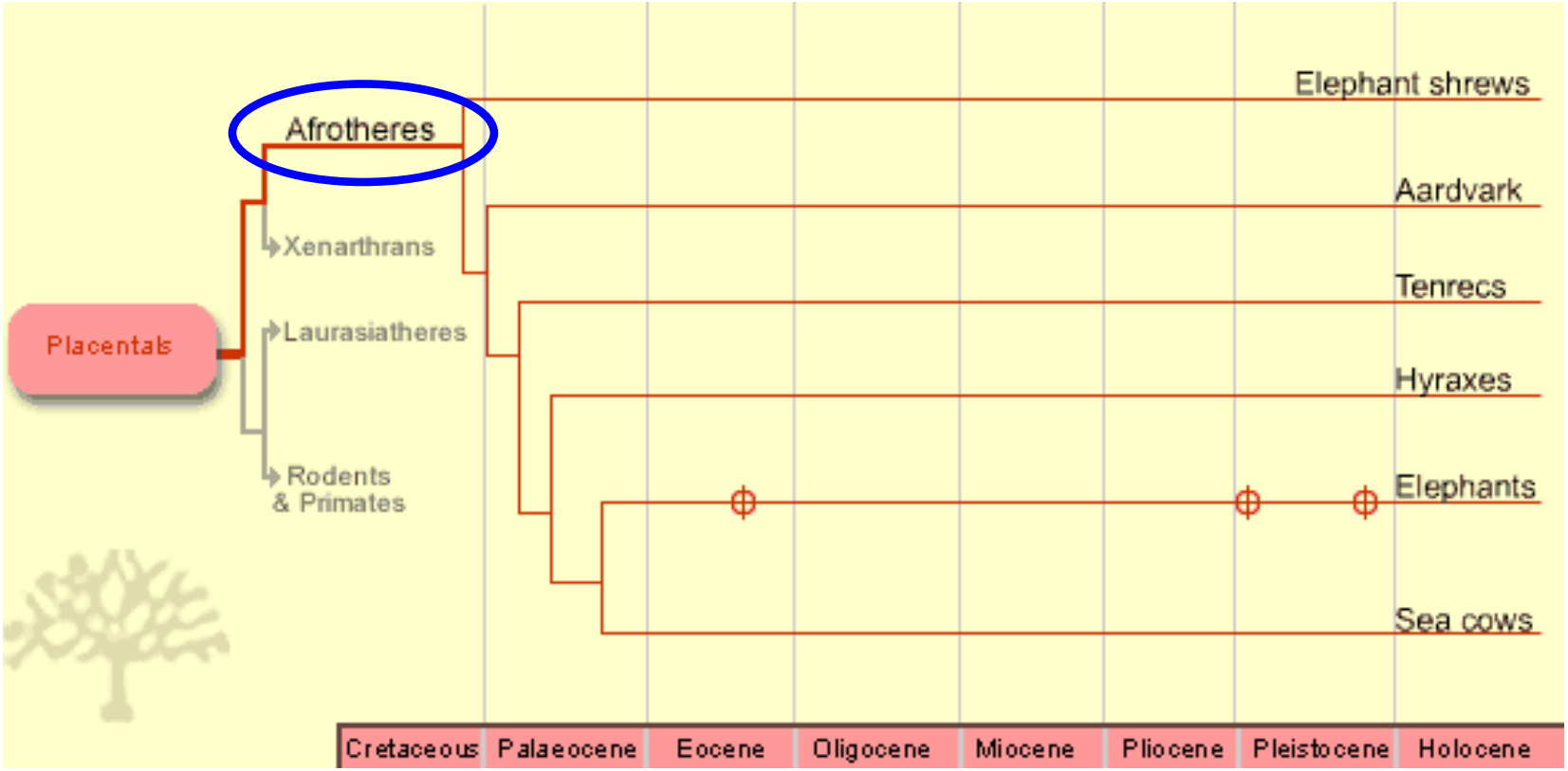
90 mya - separation of tropical South America and Africa

135 mya - separation of Gondwana

Southern Hemisphere Faunal Relationships

The lineage **Afrotheria** has been evolving in isolation for 85-90 my and includes quite divergent and once considered totally unrelated mammals

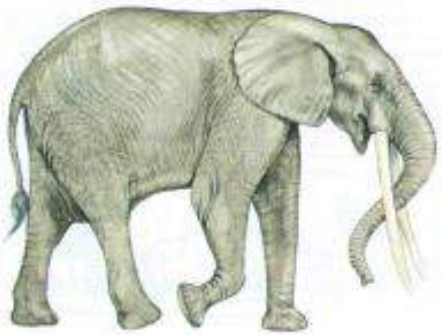




Southern Hemisphere Faunal Relationships

Representatives of the six orders comprising the Superorder Afrotheria — a striking case of **divergence** within a lineage

African forest elephant

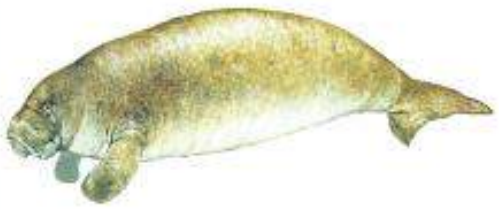


Golden-rumped elephant shrew

Aardvark

Streaked tenrec

Eastern tree hyrax



Dugong, sea cows

Southern Hemisphere Faunal Relationships

Despite isolation of South American and African mammal lineages – still recent trans-Atlantic dispersal

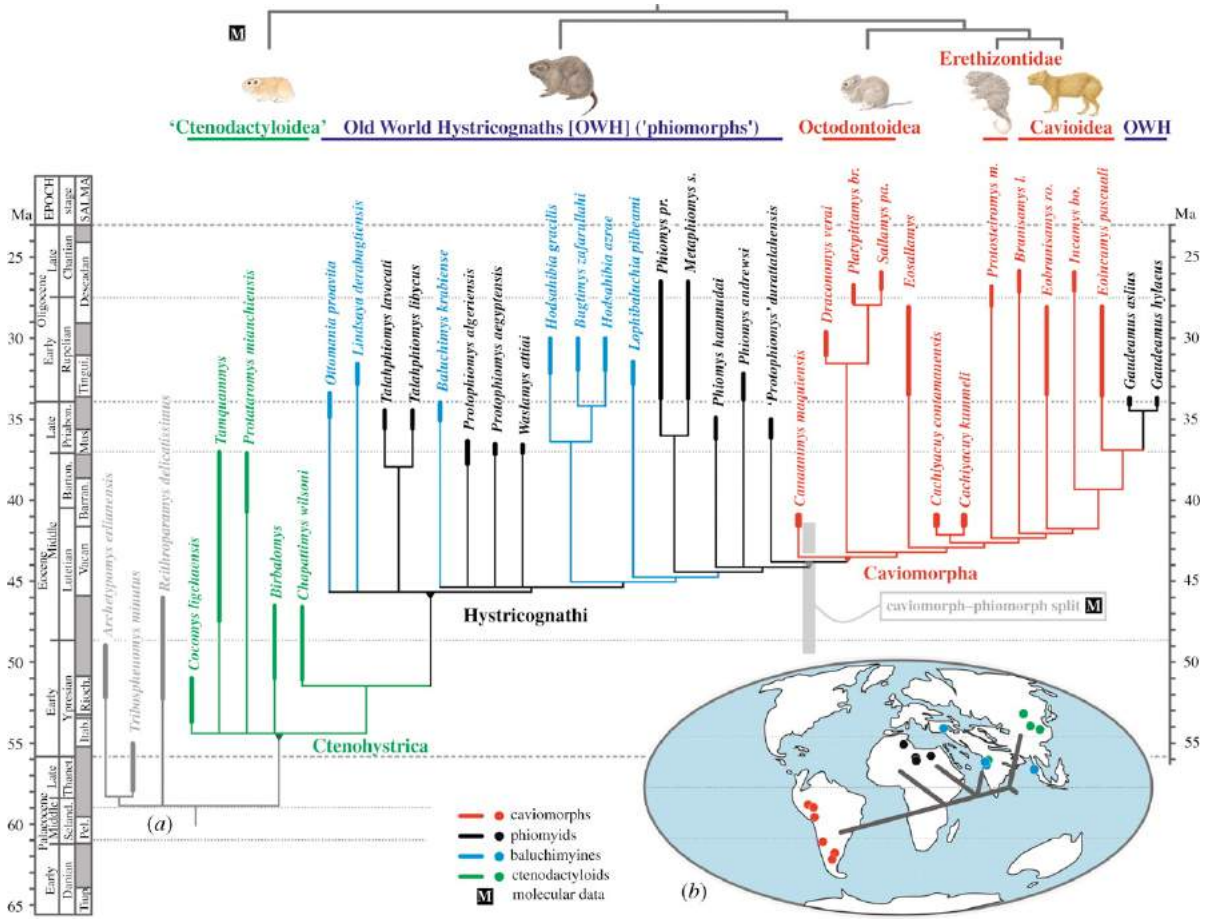
Capybara (*Hydrochoerus hydrochaeris*)

Journal of Biogeography (J. Biogeogr.) (2010) **37**, 305–324

ORIGINAL ARTICLE

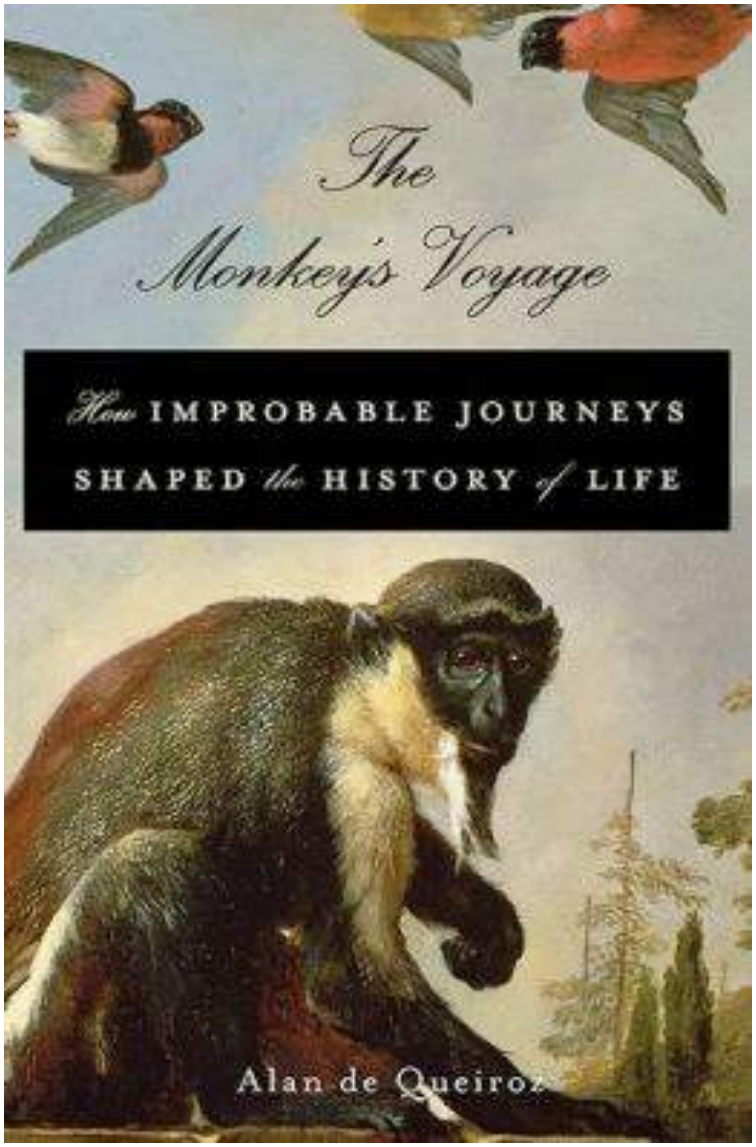
Molecular clocks keep dispersal hypotheses afloat: evidence for trans-Atlantic rafting by rodents

Diane L. Rowe[1,2*], Katherine A. Dunn[3], Ronald M. Adkins[4] and Rodney L. Honeycutt[5,2]

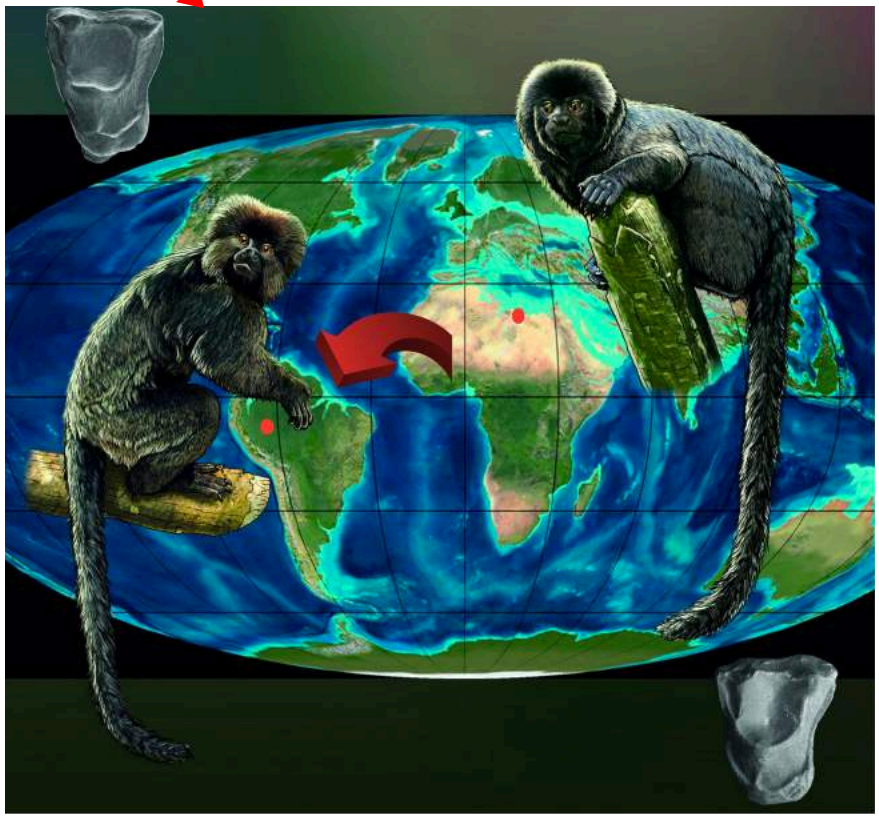


Southern Hemisphere Faunal Relationships

D in Peruespite isolation of South American and African mammal lineages – still recent trans-Atlantic dispersal



36 mya fossil monkey teeth - Peru



Eocene primates of South America and the African origins of New World monkeys – *Bond et al. (2015) Nature*