Relationships of Floras (& Faunas)

We will begin to look at several examples of relationships of disjunct groups of plants and animals by combining earth and organismal history.

There are other more “simple” tools to evaluate floristic and faunistic relationships besides those involving phylogenetics and earth history as just discussed.
One common method is to simply compare different regions in terms of \% similarity at a specific taxonomic level — as here with families of mammals and flowering plants.

However, families, or any other taxonomic rank, are not usually equivalent in age.
Floristic relationships among the afroalpine regions of the East African mountains were assessed by looking at species in common.
Floristic relationships among the afroalpine regions of the East African mountains were assessed by looking at species in common.
**Relationships of Floras (& Faunas)**

Pairwise similarity (shared species) between nine afroalpine regions. Total number of species for each mountain shown in parenthesis and endemics in bold.

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*Mt. Kenya*
Spatial distribution of nine mountains (A) and cluster diagram showing floristic relationships based on Jaccard’s coefficient of similarity (B)
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
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!
Continents, Clades, and Clocks

Maximum likelihood tree with different DNA rates along each branch

DNA “rate smoothed” tree

Biogeographical interpretation

2 dispersals!
Relationships of Floras (& Faunas)

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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. *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”!

[Image of Proteaceae flowers] [Map of Southern Hemisphere with Proteaceae distribution]
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
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”!**

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**Southern Hemisphere Temperate Flora**

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Fynbos, S. Africa
— Restionaceae
Why is Africa the “odd continent out” when it comes to the *temperate* southern hemisphere flora?

Three reasons:

**Southern Hemisphere Temperate Flora**

- **Proteaceae**
- **Restionaceae**
- **Nothofagaceae**
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.
Are all southern hemisphere disjunct patterns to be explained by vicariance (i.e., continental drift)?

We can get information about continents, the relationships of organisms or clades, but we still have little knowledge about timing of events or a clock.

Southern Hemisphere Temperate Flora

*Fuchsia*  
*Nothofagus*
Recent molecular phylogenetic tree (excluding New Guinea and New Caledonia species)

Time calibrated phylogeny plus fossil evidence indicates more than vicariance
Southern Hemisphere Temperate Flora

Example of *Fuchsia* with an Old World - New World disjunction: *integrating continents, clades, and clocks*

*Fuchsia* - evening primrose family - & hummingbird pollinator in Central America
Sections of *Fuchsia*  
(110 species)
**South America**

*Quelusia & Kierschlegeria* – 8 species in SE Brazil, & 2 in S Andes, main source of ornamental species & cultivars

*Fuchsia* - 64 spp, tropical Andes

*Hemsleyella* - 15 spp, tropical Andes, no petals, tuberous, seasonal
Central America

*Ellobium* – *F. splendens*

*Encliandra* – *F. thymifolia*

*Schufia* – *F. arborescens*
Section *Skinnera* – New Zealand

... and Tahiti

*Fuchsia excorticata*

honeyeater - pollinated
Model 1 of *Fuchsia* sect. *Skinnera* evolution

1. *Fuchsia* evolves in temperate South America
2. Early dispersal to Tahiti
3. Secondary dispersal to New Zealand
4. Evolution of male sterility followed by female sterility and flavone sulphates

Raven 1972
**Fuchsia** fossils in Australasia

*Fuchsia antiqua* flower  
(Miocene ~23mya)

*Koninidites (“Diporites”)* pollen (Oligocene ~30mya)

Berry et al. (1990)

Lee et al. (2013)
Model 2 of *Fuchsia* sect. *Skinnera* evolution

Berry et al. 1990; Sytsma et al. 1991; Sytsma & Smith 1992

1. *Fuchsia* evolves in temperate South America

2. Overland migration to Australia via Antarctica. 30 – 50 m.y. BP

3. Dispersal to New Zealand

4. Extinction of *Fuchsia* in Antarctica and Australia

5. Recent secondary dispersal to Tahiti

6. Loss of male sterility and flavone sulphates
... and later divergence of Old World sections, support vicariant hypotheses

... early separation of temperate South American sections ...

Fuchsia
Hemsleyella
Verrucosa
Skinnera & Procumbentes
Encliandra
Schufia & Jimenezia
Ellobium
Quelusia & Kierschlegeria

- F. lycioides
- Circaea alpina
- Circaea erubescens
- Circaea repens
- Circaea mollis

Tropical Andes
Mexico–Central America
Caribbean
Brazil
Southern Andes
Old World
Circumboreal

1. Fuchsia evolves in temperate South America
2. Overland migration to Australia via Antarctica
3. Recent secondary dispersal to Tahiti
4. Extinction of Fuchsia in Antarctica and Australia
5. Loss of male sterility and flavone sulphonates

Eocene | Oligocene | Miocene | Plio. Quat.
40 | 30 | 20 | 10 | 0

F. magdalenae
F. campii
F. vulcanica
F. ampliata
F. steyermarkii
F. macrostigma
F. mathewsi
F. rivalaris
F.онтинас
F. lehmannii
F. andrei
F. dependens
F. hartwegii
F. nigricans
F. corollata
F. sesilifolia
F. boliviana
F. sanctae−roae
F. denticulata
F. austromontana
F. tincta
F. vargasiana
F. pachyrhiza
F. simplicicaulis
F. coriacifolia
F. pilosa
F. triphylla
F. pringsheimii
F. apetala
F. reistroides
F. inflata
F. insignis
F. tillelliana
F. pilaoensis
F. salicifolia
F. juntasensis
F. chloroloba
F. verrucosa
F. verrucosa
F. excorticata
F. x colensoi
F. cyrtandroides
F. procumbens
F. cylindracea
F. thyoides
F. ravenii
F. encliandra
F. microphylla
F. paniculata
F. arborescens
F. jimenezii
F. splendens
F. fulgens
F. regia serra
F. hatchesbachii
F. glaziowiana
F. coccinea
F. brevilobis
F. brachelinae
F. campos−portoi
F. regia
F. magellanica
Fuchsia lycoïdes
Circaea alpina
Circaea cordata
Circaea repens
Circaea mollis
Radiation of sects. *Fuchsia & Hemsleyella* dated at ~23 mya, consistent with initial orogeny of the Andean mountains . . .
Radiation of sects. *Fuchsia* & *Hemsleyella* dated at ~23 mya, consistent with initial orogeny of the Andean mountains and some of their pollinators

McGuire et al. (2014)
Vicariance vs. Dispersal?

Temperate Gondwanan disjuncts – vicariance and/or dispersal

**Timing** of organism divergence vs. geological divergence critical & importance of temperate Antarctica

*Nothofagus*  
southern beeches

*Fuchsia*  
fuchsias

Jurassic – Cretaceous border ~ 150 million years ago
Vicariance vs. Dispersal?

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

marsupial disjunction between South America and Australia vicariance or dispersal?

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

Figure 2. Phylogenetic tree of marsupials derived from retroposon data.

The tree topology is based on a presence/absence retroposon matrix (Table 1) implemented in a heuristic parsimony analysis (Figure S3). The names of the seven marsupial orders are shown in red, and the icons are representative of each of the orders: Didelphimorphia, Virginia opossum; Paucituberculata, shrew opossum; Microbiotheria, monito del monte; Notoryctemorphia, marsupial mole; Dasyuromorphia, Tasmanian devil; Peramelemorphia, bilby; Diprotodontia, kangaroo. Phylogenetically

However, both studies gave low support for the position of Microbiotheria, illustrating the difficulties in resolving a short reconstruction when mixed with nuclear data.

The position of Microbiotheria has been intensely debated since long ago, but it was demonstrated for the incorrect position of Monotremata genes [4,17,19], invalidates the mitochondrial results [3,16,23].

Tracking marsupial evolution using genomic data - marsupial and placental mammals diverged in the Late Cretaceous ~85 Ma...
Fossils of both marsupials and placental mammals found in Antarctica

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

Distribution of Monimiaceae – an early-diverging angiosperm family

Siparuna
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!

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

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

Stegolepis hitchcockii
Amphiphyllum rigidum
Epidryos guayanensis
Schoenocephalium cucullatum
Guacamaya superba
Kunhardtia radiata
Saxofridericia regalis
Saxofridericia inermis
Monotrema bracteatum
Potarophyllum riparium
Windsorina guianensis

Stegolepidieae
Schoenocephalieae
Saxofridericieae
Monotremeae
Rapateeae

Maschalocephalus dinklagei
Rapatea paludosa
Cephalostemom affinis
Spathanthes bicolor
Spathanthes unilateralis

87 40 30 20 10 0 Mya
Bromeliaceae (pineapples) is an American family

1 species of *Pitcairnia* in west Africa - vicariance or dispersal?
Rate smoothed with PL using 8 fossils in an across monocot survey (Givnish et al. 2011)

**Bromeliaceae**

8-gene ML tree

**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* — fleshy fruited and bird dispersed

*Rhipsalis baccifera*

*Rhipsalis horrida*
South American - west African Disjuncts

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

*Humiriaceae*
8 / 50 spp

*S. amazonica* - water dispersed fruit
Boreotropics Hypothesis

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

Pantropical distribution of Malpighiaceae

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
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
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**
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