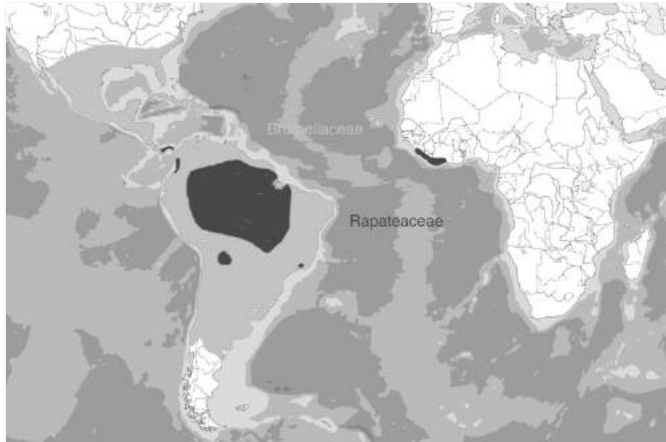
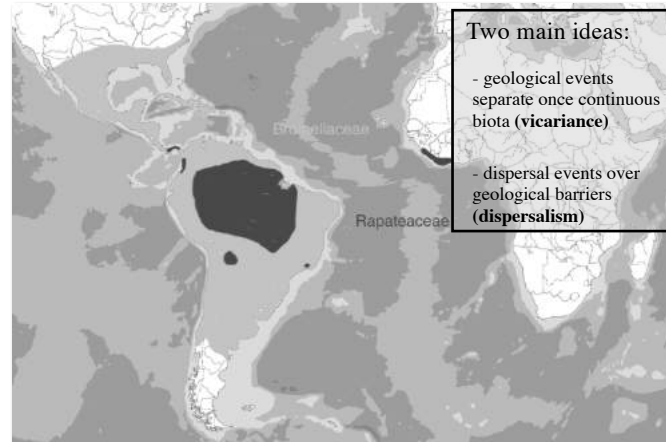


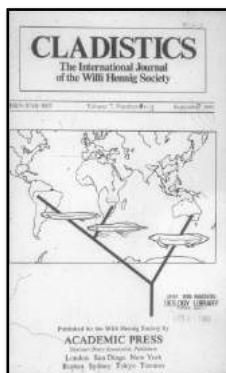
## Historical Biogeography - A History of Ideas



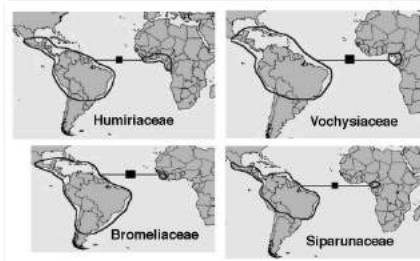
## Disjunctions: how are these distribution patterns explained?



## Disjunctions: how are these distribution patterns explained?



Vicariance paradigm:  
- invoked by the schools of vicariance biogeography and panbiogeography



Atlantic baseline - panbiogeography

## Disjunctions: how are these distribution patterns explained?



Dispersalist paradigm:

- invoked by the Wallace-Darwin tradition and island biogeographers

## Vicariance vs. Dispersal similar pattern, different process

Vicariance



Disjunct (vicariad) species  
Disjunct continental areas

Dispersal



Disjunct species  
Disjunct continental areas

## Vicariance vs. Dispersal similar pattern, different process

Vicariance



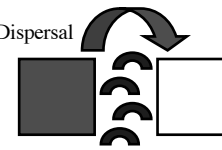
Widespread species  
Continuous continental area  
No pre-existing barrier

Erection of ocean  
barrier  
→  
Divergence in  
isolation



Disjunct (vicariad) species  
Disjunct continental areas

Dispersal



Species limited to one area  
Disjunct continental areas  
Pre-existing barrier

Dispersal across ocean  
barrier  
→  
Divergence in  
isolation

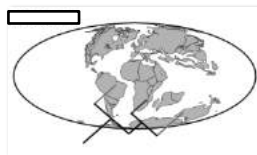


Disjunct species  
Disjunct continental areas

## 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.



Repeated pattern? - then vicariance

Vicariance



Disjunct (vicariad) species  
Disjunct continental areas

Dispersal



Disjunct species  
Disjunct continental areas

## Species and Areas: History of Ideas

Carolus Linnaeus (1707–1778)

- Swedish naturalist and taxonomist
- Developed a system to classify life that included binomial nomenclature
- Believed in special creation and thought it was his task to catalogue all of God's creations — called himself “God’s Registrar”.



Because he thought species were immutable, a question that he pondered was:

*How did different species become adapted to so many different environments?*

### Species and Areas: History of Ideas

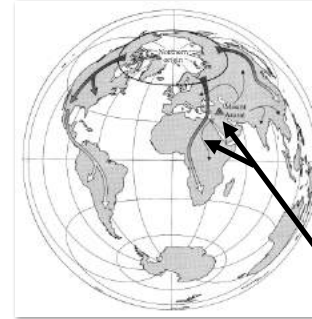
Carolus Linnaeus (1707–1778)



*“the continents in the first ages of the world lay immersed under the sea, except a single island in the midst of this immense ocean; where all animals lived commodiously, and vegetables were produced in the greatest luxuriance” (Linnaeus, 1781)*

### Species and Areas: History of Ideas

Carolus Linnaeus (1707–1778)



His explanation (Center of Origin - Dispersal idea) was that Noah's Ark had come to rest on Mount Ararat

- This tall mountain had many different elevational zones
- Each immutable species was already adapted to a particular zone
- Each species spreads out to its respective environment over the globe

### Species and Areas: History of Ideas

Comte de Buffon (1707–1788)

The naturalist de Buffon had two problems with Linnaeus' view of the origin and spread of life.

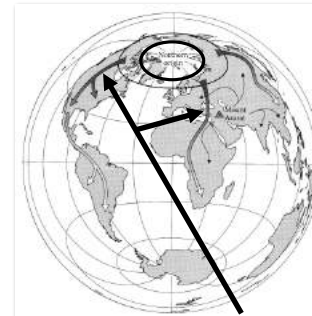
(1) He observed that different parts of the world, even those with similar conditions, were inhabited by distinct kinds of plants and animals.

(1) He found it unlikely that all species would be able to disperse across inhospitable habitats (and there were many inhospitable barriers).



### Species and Areas: History of Ideas

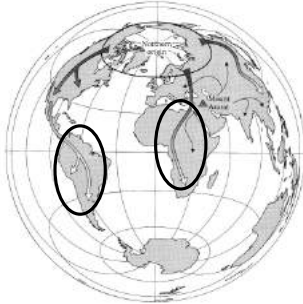
Comte de Buffon (1707–1788)



- Life originated on northern landmasses (Center of Origin)
- Life spread southward (Dispersal) as climates cooled
- Adapting and “evolving” such that each area came to contain distinct species

## Species and Areas: History of Ideas

Comte de Buffon (1707–1788)

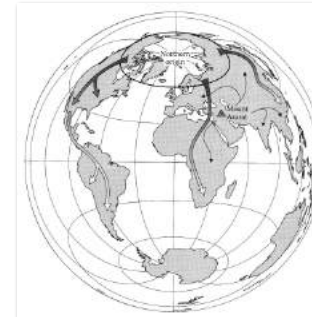


**Buffon's Law** — environmentally similar but isolated regions have distinct assemblages of mammals and birds (this is often considered the *first principle of biogeography*) [like Humboldt's idea]

Two important concepts expressed by Buffon are now central to modern biogeography: *climates and species are mutable* (changeable)



## Species and Areas: History of Ideas



1. "Center of Origin" from which species originate and disperse
2. Ecological conditions control the regularities in distribution patterns

Thus before end of the 18th century, two important ideas had emerged concerning the nature of the distribution of species around the world:

## Species and Areas: History of Ideas

Karl Willdenow (1765–1812)

German botanist, provided a major treatise on plant geography. He described the floristic provinces of Europe and offered a novel interpretation for their origin as well as others in the southern hemisphere.

*"Lands now separated by oceans may, in former epochs, have been united. . . . Thus, the northern part of America may have been connected with Europe, New Netherlands [Australia] with the foothills of the Cape of Good Hope"*

Willdenow (1798)

one of the first "vicariance" thoughts!



## Species and Areas: History of Ideas

Alexander von Humboldt (1769–1859)



Despite Willdenow's foresight, Humboldt articulated the first vicariance argument . . .

*"In order to come to a decision as to the existence in ancient times of a connection between neighboring continents, geology bases itself on the analogous structures of coastlines, on the similarity of animals inhabiting them and on ocean surroundings. Plant geography furnishes most important material for this kind of research . . . it finds the separation of Africa and South American occurred before the development of living organisms"* (von Humboldt and Bonpland, 1805)

## Species and Areas: History of Ideas

Alexander von Humboldt (1769–1859)



He then laid down the gauntlet on the issue between vicariance and dispersal . . .

*“ . . . It is this science which can decide whether the entire surface of the earth was covered simultaneously with diverse plants, or whether according to the ancient myths of various peoples, the globe, having regained its repose, first produced plants only in a single region from which the sea currents carried them progressively, during the course of centuries, into the more distant zones”* (von Humboldt and Bonpland, 1805)

Humboldt convinced that the history of organisms and the history of the earth were intimately linked — also convinced that the Linnaean idea that organisms originated in one area and migrated to others was wrong

## Species and Areas: History of Ideas

Alexander von Humboldt (1769–1859)



He also described how this debate could be solved . . .

*“In order to solve the great problem as to the migration of plants, plant geography descends into the bowels of the earth: there it consults the ancient monuments which nature has left in the form of petrifications in the fossil wood and coal beds which constitute the burial places of the first vegetation of our planet”* (von Humboldt and Bonpland, 1805)

. . . and that this study of paleobotany would provide clues about the distribution of plants around the globe and clues to what the past climates would have been like

## Species and Areas: History of Ideas



By the turn of the 19th century, three sets of ideas now existed on organismal distributions:

1. “Center of Origin” from which species originate and disperse
2. Changes in earth history (vicariance) could explain present day patterns
3. Ecological conditions control the regularities in distribution patterns

## Species and Areas: History of Ideas

19th century scientists who argued for a dynamic earth:



**Adolphe Brongniart** (1801–1876) - “*Founder of paleobotany*”

- earth's climate was highly mutable
- used the fossil record to infer past climates
- found fossils of organisms adapted to tropical climates in northern Europe

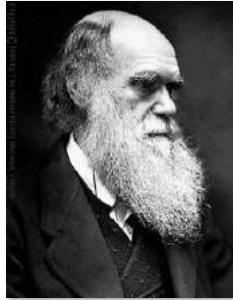


**Charles Lyell** (1797–1875) - “*Founder of Geology*” — author of “*Principles of Geology*” (1830)

- climates changed through time and found fossils adapted to different habitats than present
- documented changing sea levels and the lifting up and eroding of mountains
- recognized that the earth must be much older than just a few thousand years
- rejected the idea that species are also dynamic

## Species and Areas: History of Ideas

Charles Darwin (1809–1882)



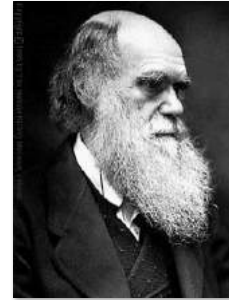
- mid 1800's – both earth and biota were mutable
- General theory to explain mutability of species came with Darwin and Wallace

Darwin responded to de Candolle's "Origin of Species" problem by saying that the similarities of biotas in the southern hemisphere were not due to changes in earth's surface but due to inheritance:

*"We see in these facts some deep organic bond, throughout space and time, over the same area of land and water, independently of physical conditions . . . The bond is simply inheritance"* (Darwin, 1859)

## Species and Areas: History of Ideas

Charles Darwin (1809–1882)



- mid 1800's – both earth and biota were mutable
- General theory to explain mutability of species came with Darwin and Wallace
- . . . and that dispersalism and extinction could account for the distribution patterns:

*"It certainly is the general rule that the area inhabited by a single species or by a group of species is continuous and the exceptions, which are not rare . . . be accounted for by former migrations under different circumstances, or through occasional means of transport, or by the species having become extinct in the intermediate tracts"* (Darwin, 1859)

## Species and Areas: History of Ideas

Alfred Russel Wallace (1823–1913)



The dispersalist ideas of Darwin were echoed by Wallace — the "father of zoogeography".

Most of his contributions to biogeography are contained in 3 books:

- "The Malay Archipelago"* (1869)
- "The Geographical Distribution of Animals"* (1876)
- "Island Life"* (1880)

## Species and Areas: History of Ideas

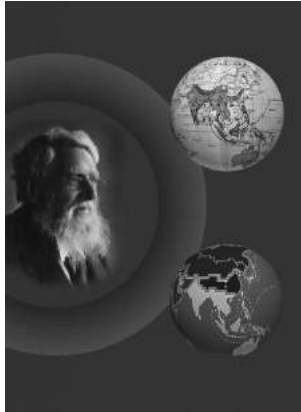
Alfred Russel Wallace (1823–1913)



The Darwin-Wallace tradition of combining species evolution and dispersalism became the dominant view during the 19th and early 20th centuries:

## Species and Areas: History of Ideas

Alfred Russel Wallace (1823–1913)



*“The north and south division truly represents that fact, that the great northern continents are the seat and birth-place of all the higher forms of life, while the southern continents have derived the greater part, if not the whole, of their vertebrate fauna from the north, but it implies the erroneous conclusion, that the chief southern lands — Australia and South America — are more closely related to each other than to the northern continent.”* (Wallace, 1876)

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## Species and Areas: History of Ideas

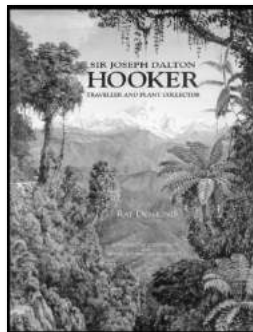
Joseph Dalton Hooker (1817–1911)



Director of the Kew Royal Botanic Garden and good friend of Darwin (the only acknowledged person in the “*Origin of Species*”) . . .

. . . but he strongly disagreed with the Darwin-Wallace dispersalist tradition

Hooker was an expert on southern hemisphere floras and believed that they represented evidence for a once more widespread flora that was subsequently broken up by geological and climatic causes.



## Species and Areas: History of Ideas

Joseph Dalton Hooker (1817–1911)



*“ . . . many of the peculiarities of the three great areas of land in the southern latitudes are representative ones, effecting a botanical relationship as strong as that which prevails throughout the lands within the Arctic and Northern Temperate zones, and which is not to be accounted for by any theory of transport or variation, but which is agreeable to the hypothesis of all being members of a once more extensive flora, which has been broken up by geological and climatic causes.”*

(Hooker, 1853)

## Species and Areas: History of Ideas

Joseph Dalton Hooker (1817–1911)



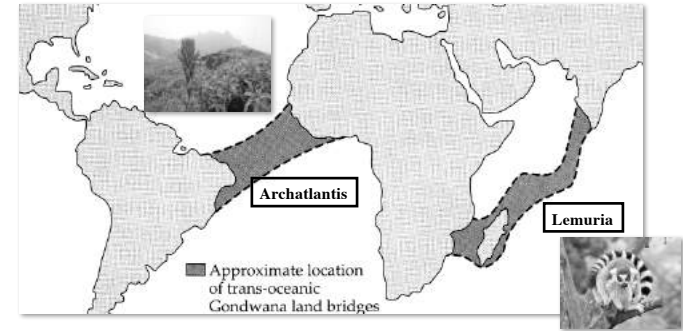
Hooker's view of the mechanism for this pattern is called extensionism — or the appeal to land bridges that have subsequently subsided — a view held by Lyell and others

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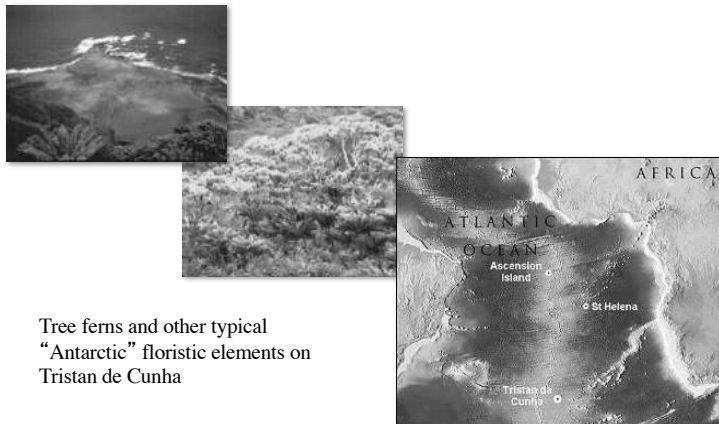
## Species and Areas: History of Ideas

**Land Bridges** — attempt to explain “vicariant” distributions of many taxa (related but disjunct biota) by presence of *former* land bridges that are now subsided; rejects long distance dispersal implied by Darwin-Wallace tradition and assumes original migration over land features subsequently disappeared.



## Species and Areas: History of Ideas

Hooker had postulated a southern continental bridge involving South America, New Zealand, Antarctica, and the Tristan de Cunha Island group



Tree ferns and other typical “Antarctic” floristic elements on Tristan de Cunha

## Species and Areas: History of Ideas

Tension between Darwin and Hooker clearly visible in this letter from Darwin —

LETTER 48. TO J.D. HOOKER. Down, July 5th [1856].

*“I write this morning in great tribulation about Tristan d'Acunha. Though Tristan d'Acunha is “only 1,000 miles distant from the Cape of Good Hope, and 3,000 from the Strait of Magalhaens, the botany of this island is far more intimately allied to that of Fuegia than Africa.” The more I reflect on your Antarctic flora the more I am astounded. You give all the facts so clearly and fully, that it is impossible to help speculating on the subject; but it drives me to despair, for I cannot gulp down your continent; and not being able to do so gives, in my eyes, the multiple creationists an awful triumph. It is a wondrous case, and how strange that A. De Candolle should have ignored it; which he certainly has, as it seems to me. I wrote Lyell a long geological letter about continents, and I have had a very long and interesting answer; but I cannot in the least gather his opinion about all your continental extensionists; and I have written again beseeching a verdict.”*



## Species and Areas: History of Ideas

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## Species and Areas: History of Ideas

**Land Bridges** — subsequently criticized by biogeographers (wrong answer for the correct question) as "bridge building" to address any disjunct pattern.

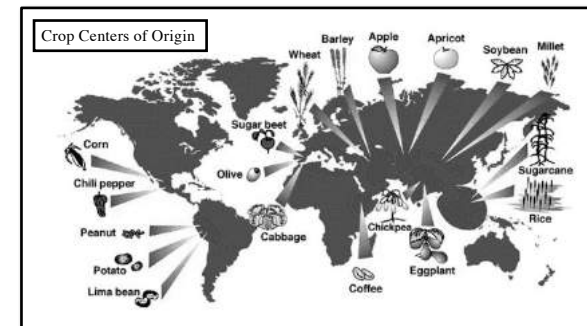
Some, like *Beringia*, will be validated later; other floristic patterns will have other explanations besides land bridges or dispersal.



## Species and Areas: History of Ideas

Recent dispersalist ideas: Center of Origin

When considering the history of a biota in a particular area, the dispersal biogeographer asks: where did the group originate?



## Species and Areas: History of Ideas

Recent dispersalist ideas: Center of Origin

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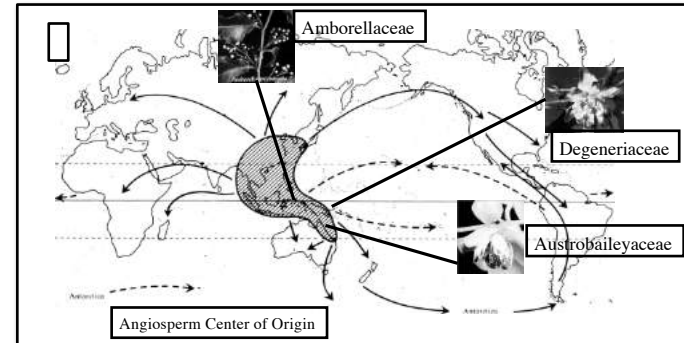
13 guides to determine the "center of origin" (Cain, 1944)

- The location of the greatest variety of forms of the taxon
- The location of the area of greatest dominance and density of distribution
- The location of the most primitive forms
- The location of least dependence on a restricted habitat
- The concentricity of progressive equiformal areas

## Species and Areas: History of Ideas

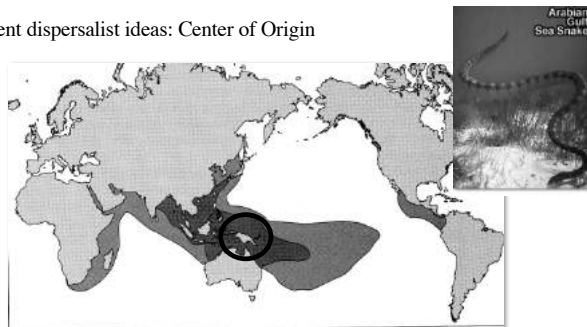
Recent dispersalist ideas: Center of Origin

Angiosperm Center of Origin often placed in Australasia as many putative primitive families are endemic there [*The location of the most "primitive" forms*]



## Species and Areas: History of Ideas

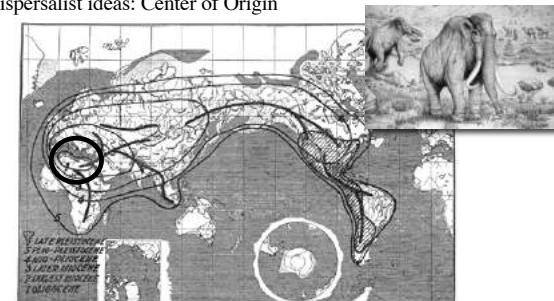
Recent dispersalist ideas: Center of Origin



Distribution of sea snakes (Hydrophiidae). All but one species are confined to the dark shaded area; most closely related relative in swamps in Australia → Center of Origin in Australia-New Guinea [*The location of the greatest variety of forms of the taxon*]

## Species and Areas: History of Ideas

Recent dispersalist ideas: Center of Origin



Concentric increasing distributions of Mastodons through time; dark lines indicate likely routes of migration → Center of Origin in northern Africa [*The concentricity of progressive equiformal areas*]

## Species and Areas: History of Ideas

Recent dispersalist ideas: Migration Routes

When considering the history of a biota in a particular area, the dispersal biogeographer asks: where did the group originate? and when and how did it come to occupy the place in which it lives today?



Simpson (1935, 1940) described three types of migration routes:

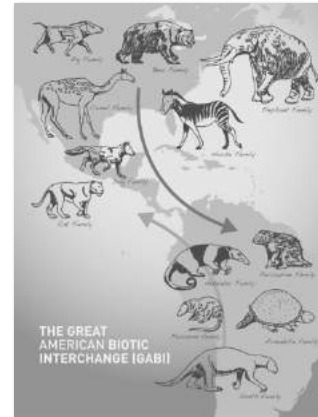
- **corridors** — heavy duty migration routes
- **filters** — light load traverses (big deserts, water gaps)
- **sweepstakes routes** — rare chance crossing of formidable barriers (oceans)

*George Gaylord Simpson*

## Species and Areas: History of Ideas

Recent dispersalist ideas: Migration Routes - corridors

*Simpson 1940 Mammals and land bridges*

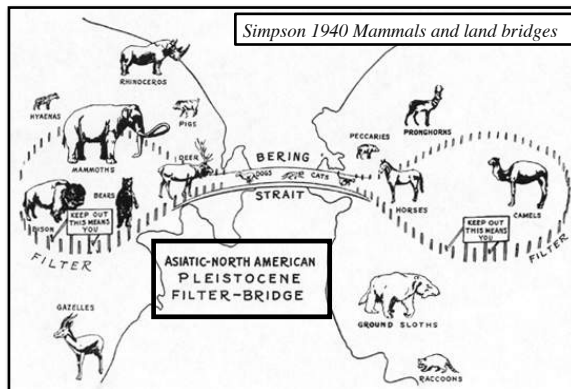


Great American fauna exchange

## Species and Areas: History of Ideas

Recent dispersalist ideas: Migration Routes - filters

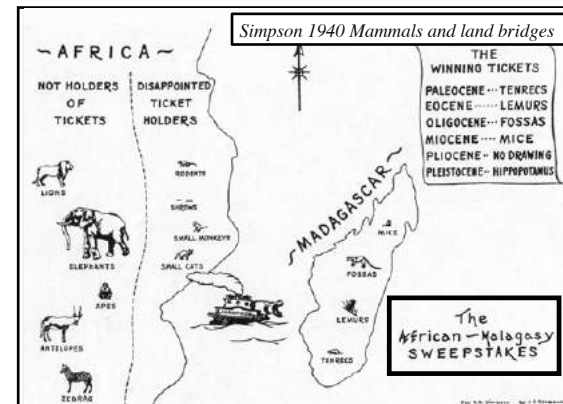
*Simpson 1940 Mammals and land bridges*



## Species and Areas: History of Ideas

Recent dispersalist ideas: Migration Routes - sweepstakes

*Simpson 1940 Mammals and land bridges*



## Species and Areas: History of Ideas

Recent *anti*-dispersalists



Donn Rosen, Gareth Nelson, Norm Platnick 1983

*"The concentration on a class of improbable dispersals as an explanation for different taxa occupying different areas of endemism results in the 'science of the rare, the mysterious and the miraculous.' Consequently, dispersal hypotheses can never let us discover the history of the earth"* (Gareth Nelson, 1978)

## Species and Areas: History of Ideas

Recent *anti*-dispersalists

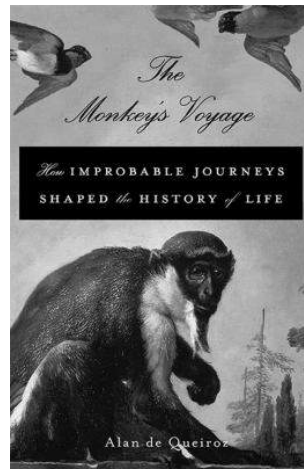


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## Species and Areas: History of Ideas

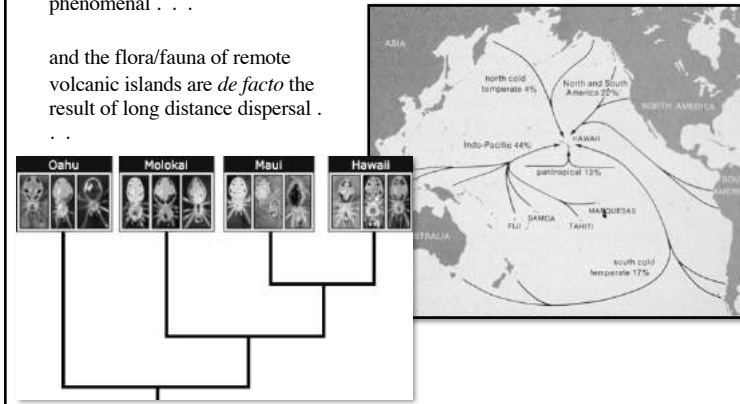
But . . . the power of long distance dispersal (LDD) in plants and animals is phenomenal . . .



## Species and Areas: History of Ideas

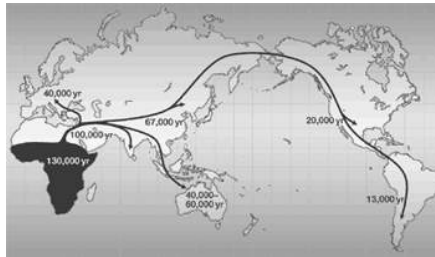
But . . . the power of long distance dispersal (LDD) in plants and animals is phenomenal . . .

and the flora/fauna of remote volcanic islands are *de facto* the result of long distance dispersal . . .



## Species and Areas: History of Ideas

and many species (not necessarily entire floras/faunas) have documented migration patterns consistent with dispersalist ideas.



*Homo sapiens*



## Species and Areas: History of Ideas

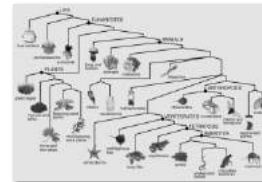
How do you choose between dispersalist and vicariance models?

Two important scientific advances – in the study of earth history and organismal history - revolutionized historical biogeography



### 1. Acceptance of plate tectonics

Up until the 1960s, most persons considered the earth's crust to be fixed. Finally, in the 1960s the geological evidence was at hand that made continental drift irrefutable.



### 2. Development of new phylogenetic methods

Willi Hennig (1950) introduced the modern concepts of phylogenetic theory (first published in 1956). Using this methodology, hypotheses of historical lineages of species could be reconstructed.