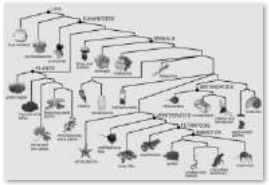
Historical Biogeography

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.

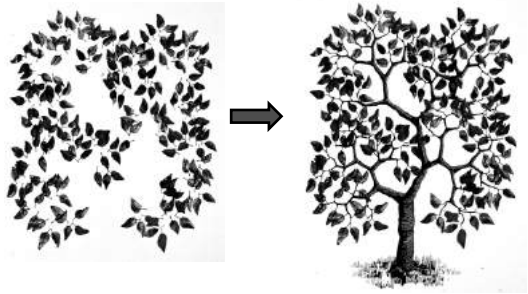


2. Development of new phylogenetic methods

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.

Phylogenetics

Before linking biogeography with phylogenetics, we need to take a closer look at how to estimate the "tree"



Usually we only have information on the "leaves" – or extant living species – and estimating the "tree" with its "branches" is not easy

Phylogenetics

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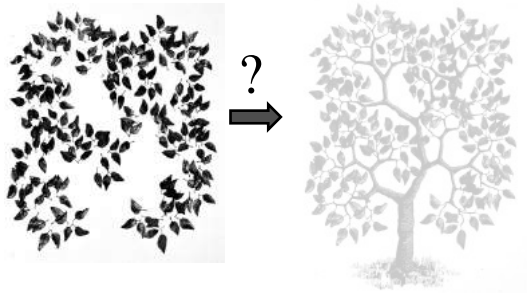

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Phylogenetics

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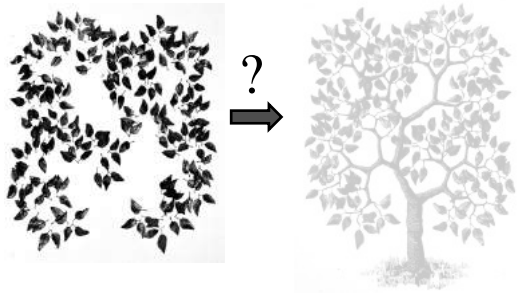


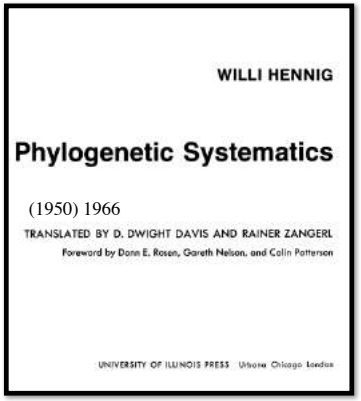
Usually we only have information on the "leaves" – or extant living species – and estimating the "tree" with its "branches" is not easy

Phylogenetics

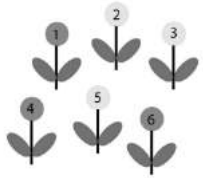
Willi Hennig (entomologist) and Walter Zimmerman (botanist) developed formal methods for reconstructing phylogenies

Hennig's book "*Phylogenetic Systematics*" was translated into English and introduced the method of phylogenetics called **cladistics**

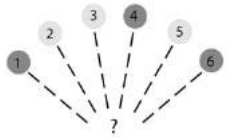

Hennig



Phylogenetics



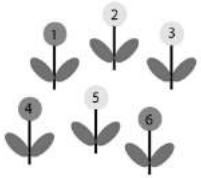
How are these 6 species of genus *Oppositifolia* related?



Cladistics forms groups based on shared-derived characters or synapomorphies

Are the blue flowers derived (apomorph) or are they primitive (plesiomorph)?

Phylogenetics

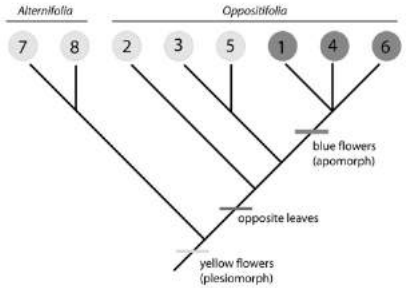


How are these 6 species of genus *Oppositifolia* related?

Use the genus *Alternifolia* as an outgroup to polarize the characters in the ingroup

Cladistics forms groups based on shared-derived characters or synapomorphies

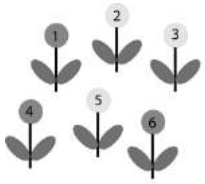
Are the blue flowers derived (apomorph) or are they primitive (plesiomorph)?



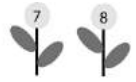
Phylogenetics

What if convergences or reversals have taken place in evolution?

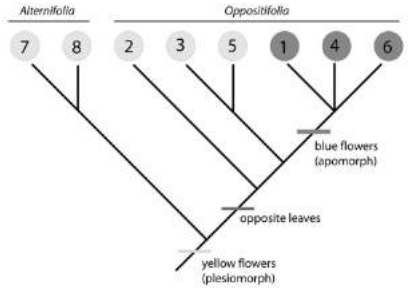
Where does this belong?



Oppositifolia species



Alternifolia species



Phylogenetics

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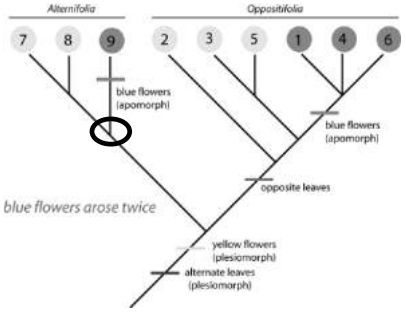
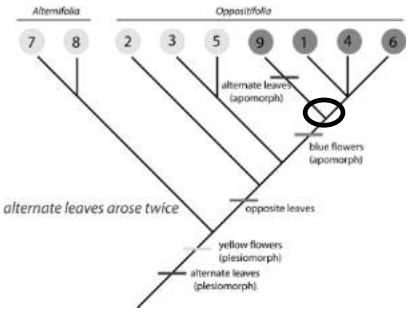


1. Belongs with other alternate leaved species; but blue flowers have evolved twice independently

Phylogenetics

What if convergences or reversals have taken place in evolution?

Where does this belong?



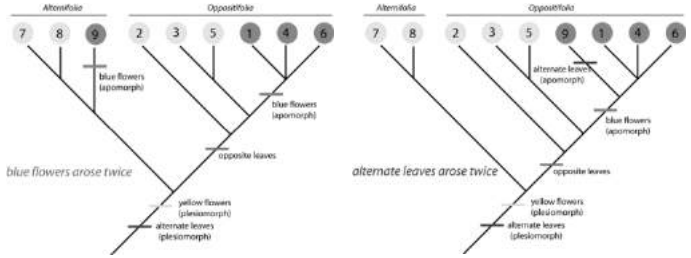
2. Belongs with other blue flowered species; but reversal back to alternate leaves has occurred

Phylogenetics

What if convergences or reversals have taken place in evolution?

Both of these phylogenetic trees are equally likely based on parsimony — they both require one extra step

Maximum parsimony, maximum likelihood, etc. used as optimality criteria in phylogenetics to choose which of potentially many different trees is best



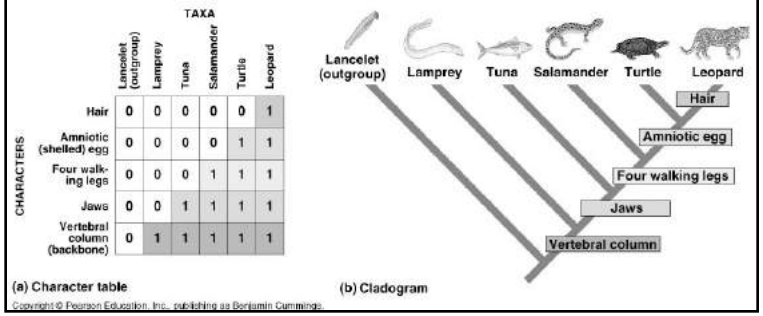
Phylogenetics

The data matrix has **taxa** each scored for as many **characters** as possible

	char 1	*char 2*	*etc.*	**(morphology)**	**(DNA)**	**(geography)**
taxon 1	**1**	**1**	**0**	**0**	**0**	**1**
taxon 2	**1**	**1**	**0**	**0**	**0**	**0**
etc.	**0**	**1**	**0**	**0**	**0**	**0**
(populations)	**0**	**1**	**0**	**0**	**0**	**0**
(species)	**0**	**0**	**0**	**0**	**1**	**0**
(families)	**0**	**0**	**1**	**1**	**1**	**0**
	0	**0**	**1**	**1**	**1**	**0**
	0	**0**	**1**	**1**	**1**	**0**

Constructing Phylogenetic Trees

https://www.youtube.com/watch?v=pwQWecIbsIc

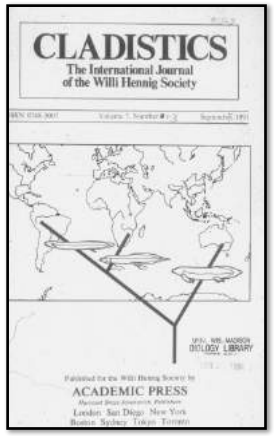


Phylogenetics

"If philosophy is the devil's whore, as Martin Luther once quipped, then biogeography and biological systematics are fast becoming Old Nick's bordello" (Craw, 1988b)

Phylogenetics and historical biogeography are now intimately intertwined . . .

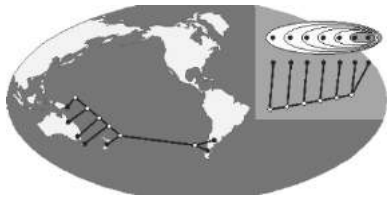
. . . and now becoming a sanctified marriage with the use of DNA – molecular phylogenetics



Phylogenetic Biogeography

Phylogenetic biogeography was the first explicit attempt to connect relationships of taxa to biogeography

Initially attempted by Willi Hennig (1968), the formulation of the method was done by the Swedish zoologist Lars Brundin and his students

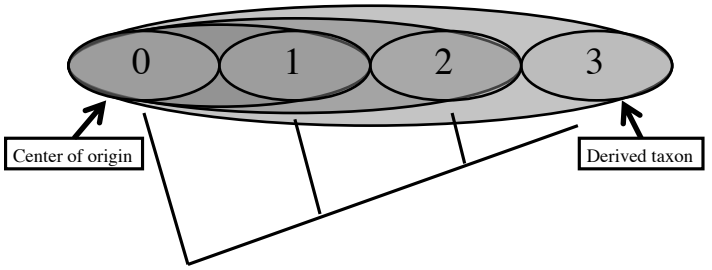


- Phylogenetic hypothesis
- "Progression rule, and Deviation rule"
- Centers of origin
- Intermediate between dispersalism and cladistic biogeography

Phylogenetic Biogeography

- *Progression rule:* **0 → 1 → 2 → 3**

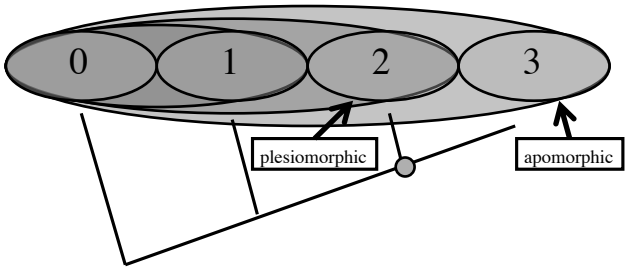
The *primitive members of a taxon are found closer to its center of origin* than more derived ones. "Peripheral allopatric speciation".



Phylogenetic Biogeography

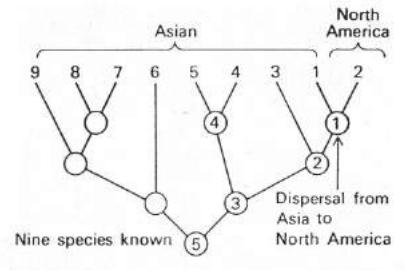
- *Deviation rule:*

  Between two sister-species, the more *plesiomorphic* species is the one present in the *original* area, whereas the more *apomorphic* is the one that *dispersed*



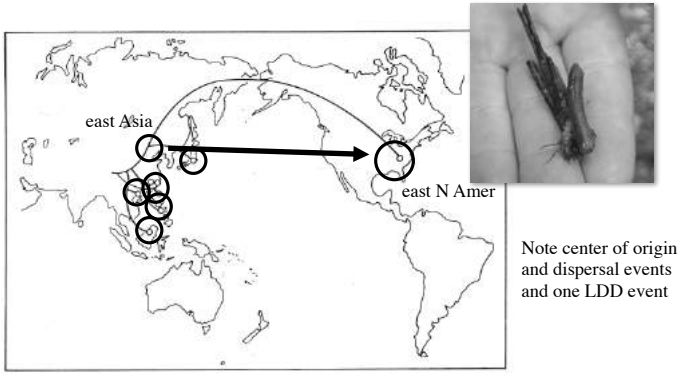
Phylogenetic Biogeography

Cladogram used with the two rules to find *center of origin* and patterns of *dispersal*



Cladogram for the nine species of *Wormaldia* (caddis flies) — Ross, 1974

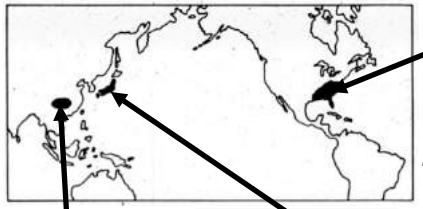
Phylogenetic Biogeography



Note center of origin and dispersal events and one LDD event

Distribution and phylogeny of *Wormaldia* (caddis flies) — Ross, 1974

Phylogenetic Biogeography



Stewartia malacodendron
Theaceae - tea family

Stewartia sinensis

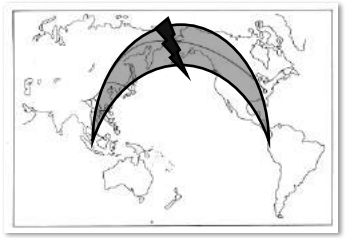
Stewartia pseudocamellia

But there are many animals and plants with this same distribution!

All explained by separate centers of origins and dispersal events?

Cladistic Biogeography

One breakthrough in the application of phylogenetics to biogeography - cladistic biogeography - came with the efforts of biogeographers such as Donn Rosen, Gareth Nelson, and Norm Platnick in their interpretation of these examples



They would interpret such a pattern as the caddis flies in a different way —

Once continuous biota . . .

and then vicariance explains this particular distribution *just as well*

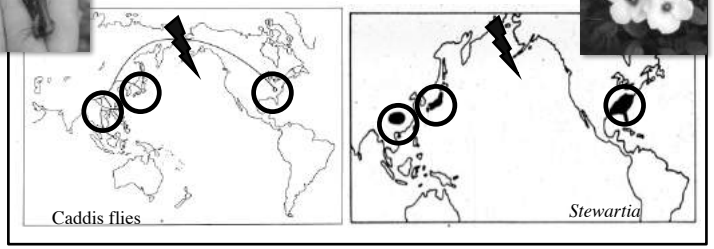
Cladistic Biogeography

One breakthrough in the application of phylogenetics to biogeography - cladistic biogeography - came with the efforts of biogeographers such as Donn Rosen, Gareth Nelson, and Norm Platnick in their interpretation of these examples

Distributional data are insufficient to resolve decisively either dispersal or vicariance as the cause of a particular disjunct distribution pattern

Cladistic Biogeography

if general pattern . . . then invoke vicariance!

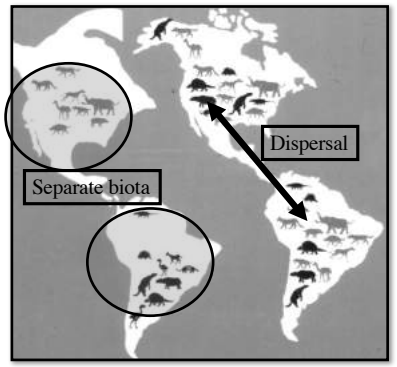


Platnick and Nelson (1978) argued that "*one should not worry about the cause of a particular distribution but whether or not it conforms to a general pattern of relationships shown by other groups of taxa endemic to the areas occupied*"

Cladistic Biogeography

Aside: perhaps these two ideas should be considered ends of a spectrum:

Completion of Panama land bridge allowed migration/dispersal of quite unrelated animal and plant taxa into the two Americas . . .

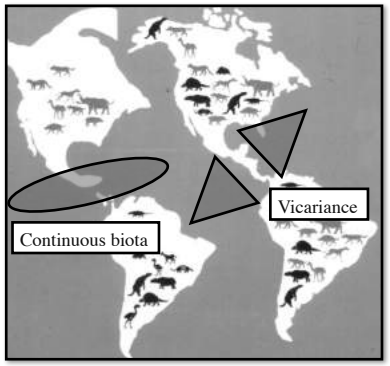


Cladistic Biogeography

Aside: perhaps these two ideas should be considered ends of a spectrum:

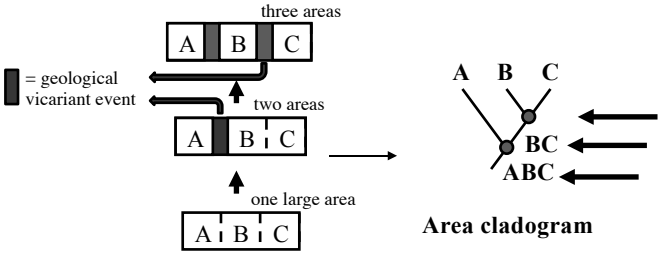
Completion of Panama land bridge allowed migration/dispersal of quite unrelated animal and plant taxa into the two Americas . . .

and at the same time provided a vicariance event in dividing a previously single community of marine organisms into separate Caribbean and East Pacific groups

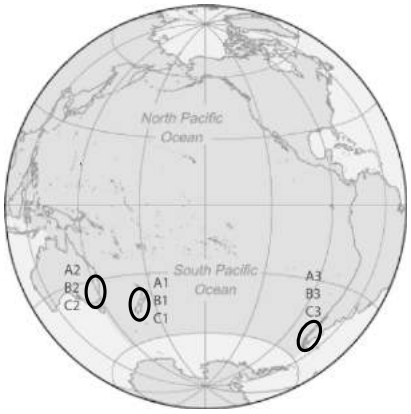


Cladistic Biogeography

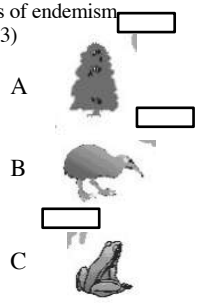
- Integration of Plate tectonics + Vicariance + Cladistics
- Correspondence between areas of distribution (A, B, C below) and phylogenetic relationships (Vicariance)



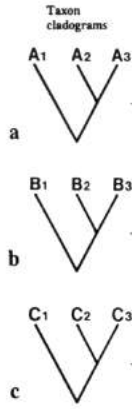
Cladistic Biogeography



Step 1 — find monophyletic groups (A,B,C) with taxa occurring in 3 or more areas of endemism (1,2,3)

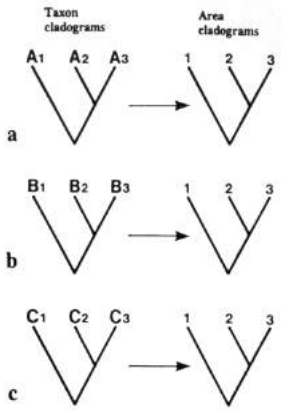


Cladistic Biogeography



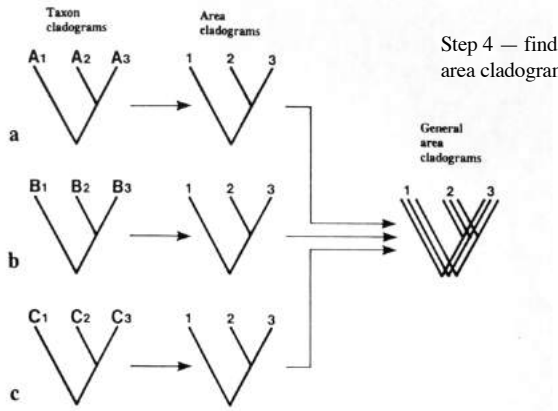
Step 2 — produce taxon cladograms for each group

Cladistic Biogeography



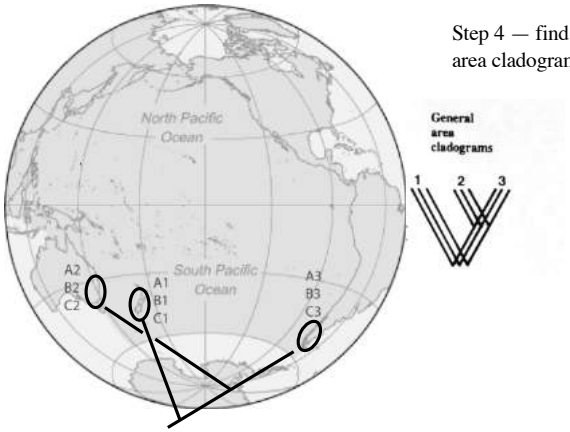
Step 3 — produce area cladograms by replacing taxon names with areas

Cladistic Biogeography



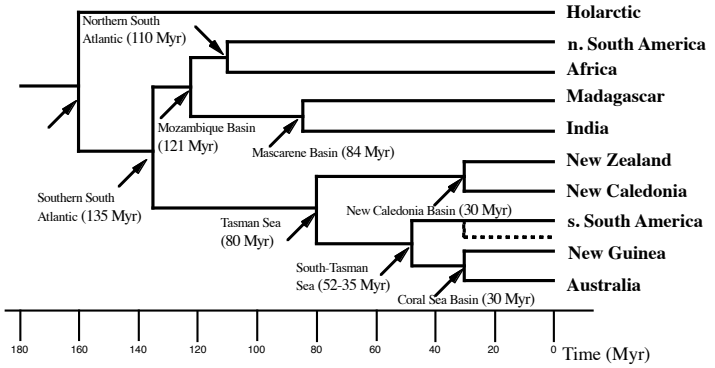
Step 4 — find general area cladogram

Cladistic Biogeography



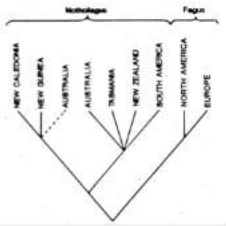
Step 4 — find general area cladogram

Cladistic Biogeography



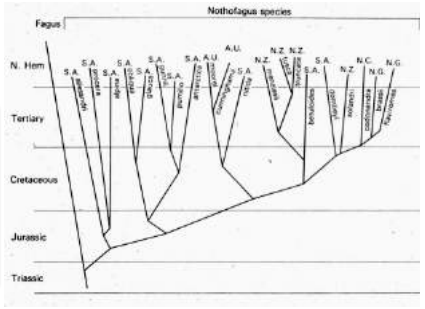
Step 5 — is general area cladogram supported by geological area cladogram?

Cladistic Biogeography



***Nothofagus* – southern beeches**
the plant example in cladistic biogeography

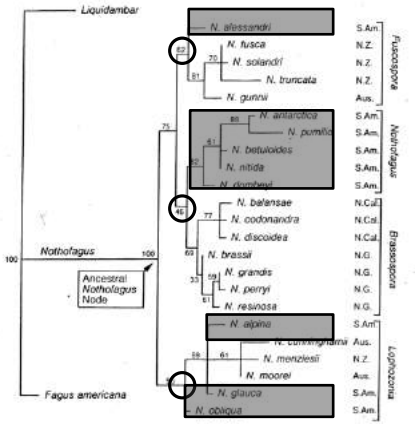
Issue #1 — cladogram accuracy: biogeographic "story" is only as good as the "estimate" of relationships of the organisms (e.g., changing idea of *Nothofagus* phylogeny)



Cladistic Biogeography

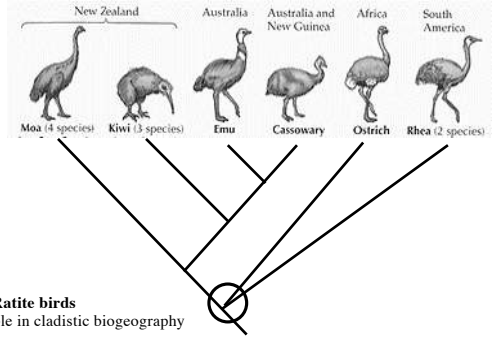
A recent molecular cladogram of *Nothofagus*; now there appears to be 3 lineages within *Nothofagus* that show independent Gondwanan vicariance with S. America splitting first

***Nothofagus* – southern beeches**
the plant example in cladistic biogeography



Cladistic Biogeography

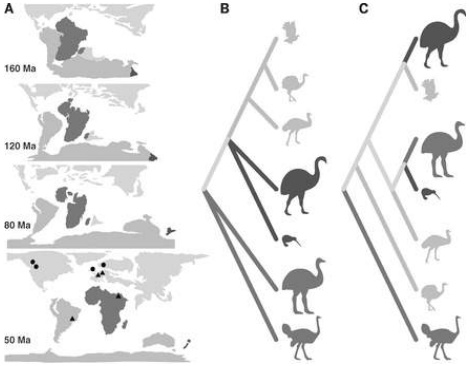
Issue #2 — unresolved cladogram: therefore unknown area relationships



Ratite birds
the animal example in cladistic biogeography

Cladistic Biogeography

Issue #2 — unresolved cladogram: therefore unknown area relationships



Also cladogram accuracy!

B. Geological story

C. Mitochondrial story (different from nuclear story)

Science 2014 Mitchell et al.

Cladistic Biogeography

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.

Cladistic Biogeography

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

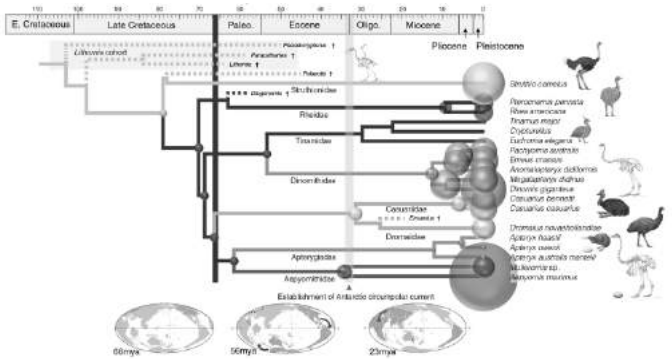
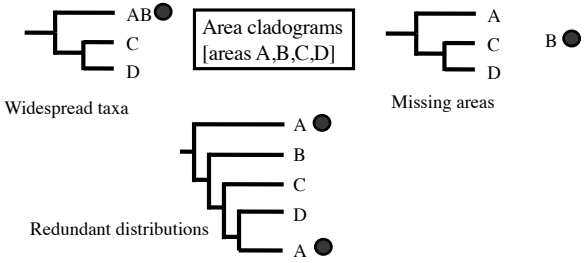


Figure 4. Palaeognathae Genomic Time Tree and Body Size

Cladistic Biogeography

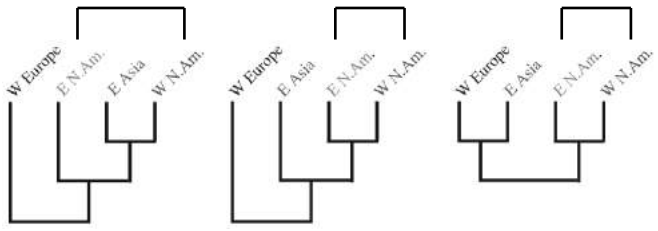
Issue #3 — taxa / area inconsistencies:

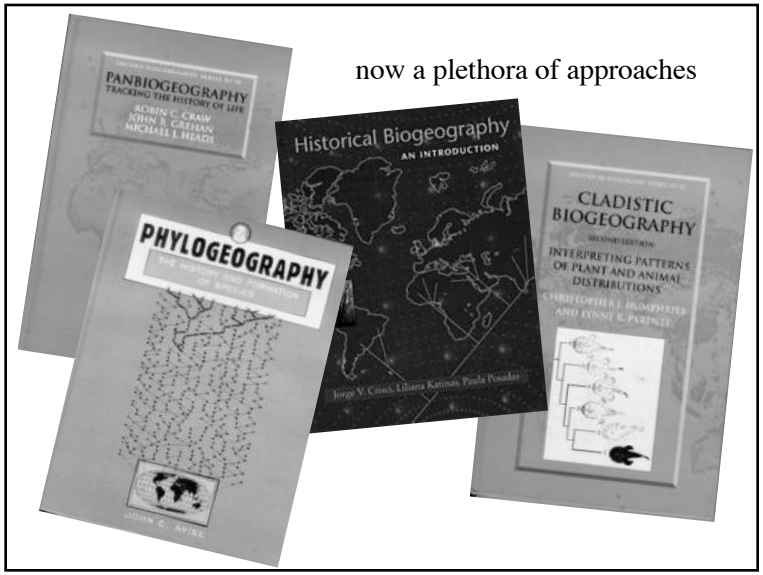
- *Widespread taxa*: Taxa present in more than one area
- *Missing areas*: Some of the areas are missing from one of the compared cladograms
- *Redundant distributions*: Areas that harbor more than one taxon



Cladistic Biogeography

Issue #4 — incongruent cladograms: different groups give different area relationships





now a plethora of approaches

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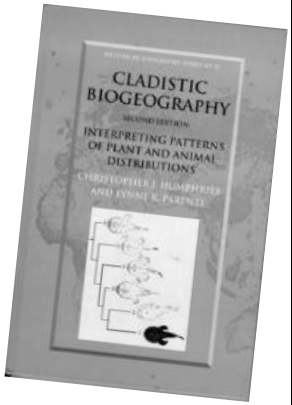
Donn Rosen, Gareth Nelson, Norm Platnick 1983



Vicariance OR dispersalism alone is not warranted

	DISPERSAL or VICARIANCE	DISPERSAL and VICARIANCE
Center of origin and dispersal		
Panbiogeography		
Phylogenetic biogeography		
Ancestral areas		
Cladistic biogeography		
Phylogeography		
DIVA		
DEC, BioGeoBEARS (DECj)		