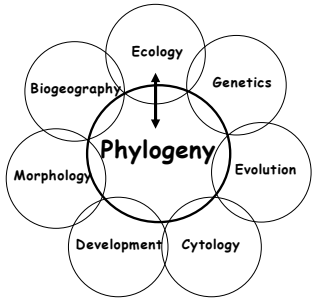
1

Future of Systematics

1. **Genomics**
2. **Biogeography**
3. Ecology

Ecology and phylogenetics intertwined **in a number of new fields of study called** Phylogenetic Ecology



2

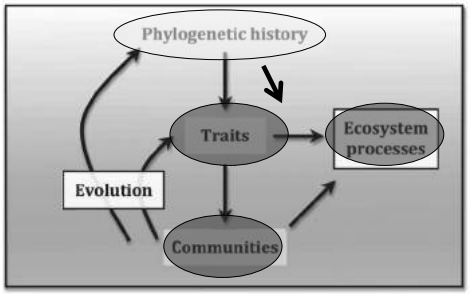
Phylogenetic Ecology

Ecology Letters, (2009) 12: 693–715 doi: 10.1111/j.1461-0248.2009.01314.x

REVIEW AND SYNTHESIS

The merging of community ecology and phylogenetic biology

Jeannine Cavender-Bares et al.



Phylogenetics can/should inform ecological processes **at many scales!**

3

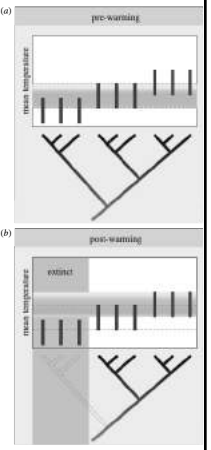
Phylogenetic Ecology

The use of phylogeny to understand species loss due to global climate change

Original habitat climate niche

Species climate niche envelope

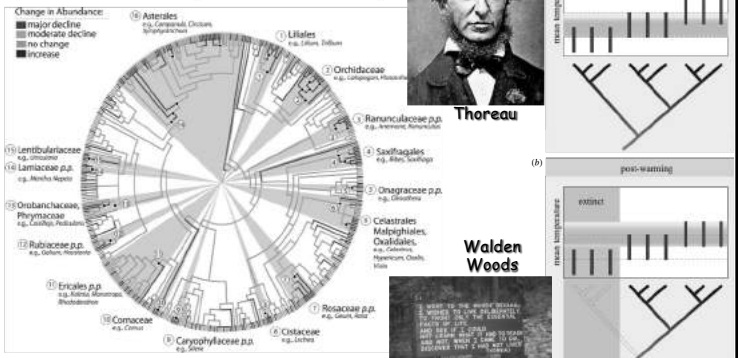
New habitat climate niche



4

Phylogenetic Ecology

The use of phylogeny to understand species loss due to global climate change



Thoreau

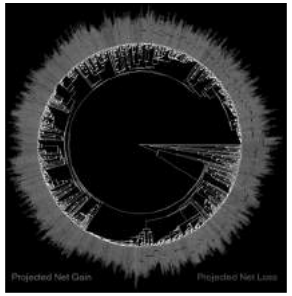
Walden Woods

Davis et al. 2010 Phil. Trans. Royal Soc. B

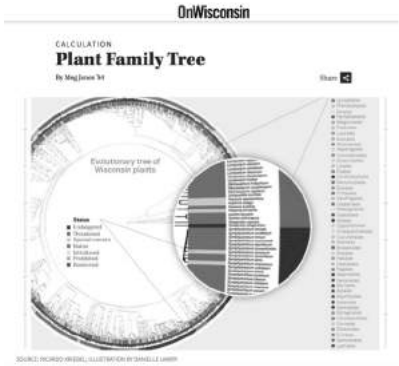
5

Phylogenetic Ecology

Projecting species niche models to 2070 under climate change model



Spalink et al. 2018 American Journal of Botany



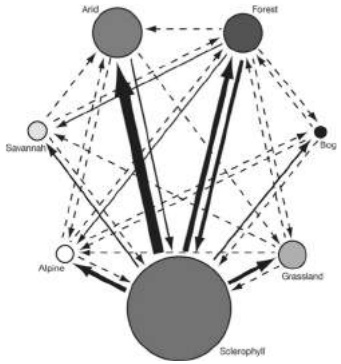
DNA Barcode phylogenetic tree of Wisconsin flora

6

Phylogenetic Ecology

Examined speciation events within Southern Hemisphere continental biome types

Michael Crisp et al. (2009) – read!

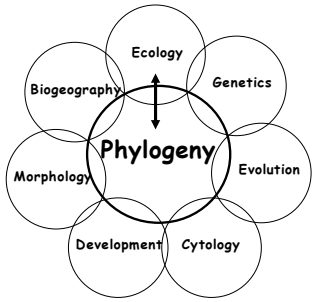


Do most transoceanic colonizations occur within same or different biome types?

7

Phylogenetic Ecology

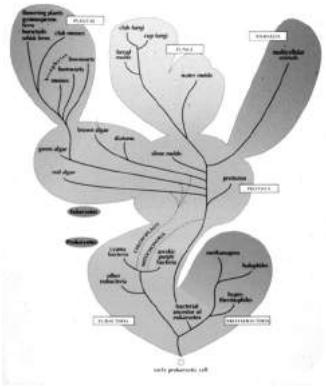
1. **Genomics**
2. **Biogeography**
3. Ecology



Ecology and phylogenetics intertwined when looking at the emergence of life forms **on earth and their subsequent diversification**

8

Emergence of Life Forms



• **emergence of** 3 domains of life with 6+ kingdoms

9

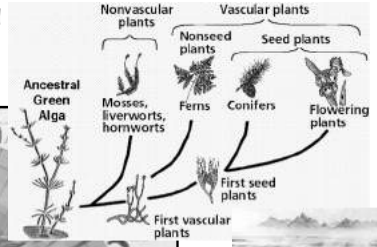
Emergence of Life Forms

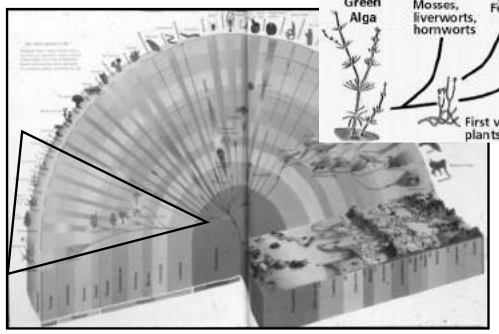
• **rise of major lineages of** eukaryota - **many of which we do not yet know how related**

10

Emergence of Life Forms

• **movement of** plants onto land **and their subsequent diversification**



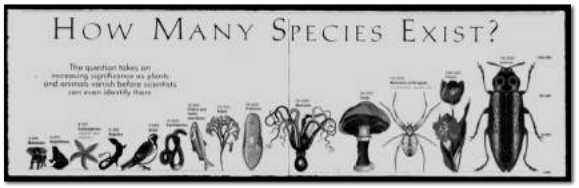


Ordovician-Devonian

11

Emergence of Life Forms

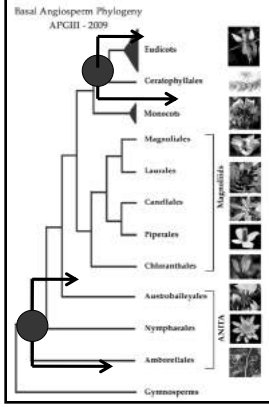
• **and finally the** rise and domination of flowering plants



12

Variation in Lineage Diversity

Variation in lineage diversity relates to the appearance of unequal numbers of species in sister lineages – unequal radiations



ca. 210,000 species eudicots

vs.

5-30 species coon's tails

What "causes" these imbalances despite same amount of time to radiate?

ca. 300,000 species all flowering plants

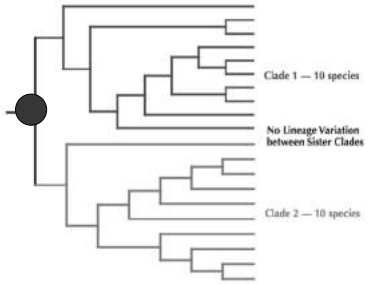
vs.

1 species *Amborella*

13

Variation in Lineage Diversity

Variation in lineage diversity relates to the appearance of unequal numbers of species in sister lineages



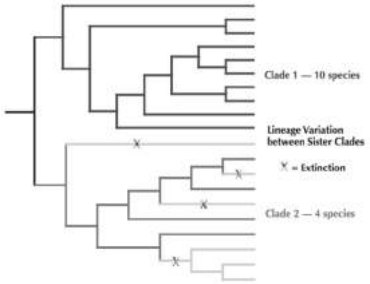
Expectation is that sister lineages should show roughly equal numbers of species - **as they are equal in age**

What are the exceptions?

14

Variation in Lineage Diversity

Variation in lineage diversity relates to the appearance of unequal numbers of species in sister lineages



1. Differential extinction

One lineage (clade 1) **is more diverse simply because the other was maladapted perhaps to a changing environment**

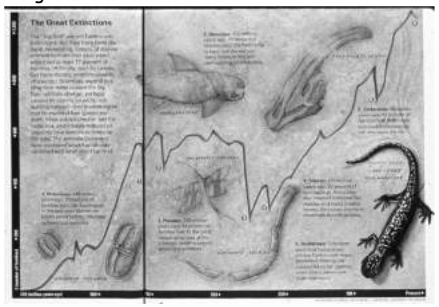
15

Variation in Lineage Diversity

Differential extinction is well known in the fossil record:

6 great extinction events

Pleistocene megafauna



16

Variation in Lineage Diversity

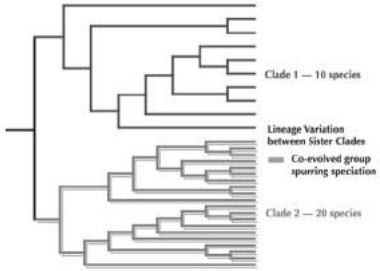
Differential extinction is well known in the fossil record:

Diverse lycopods & horsetails in Carboniferous

17

Variation in Lineage Diversity

Variation in lineage diversity relates to the appearance of unequal numbers of species in sister lineages



2. Coevolution

One lineage (clade 2) **is more diverse because of the ability to co-evolve with other organisms**

18

Variation in Lineage Diversity

Flowering plants show remarkable ability to co-evolve with other organisms: Pollination

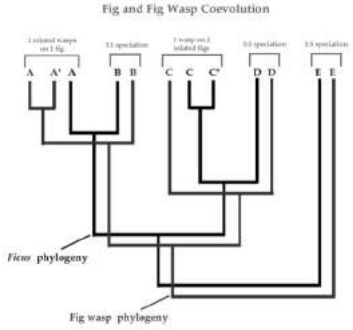
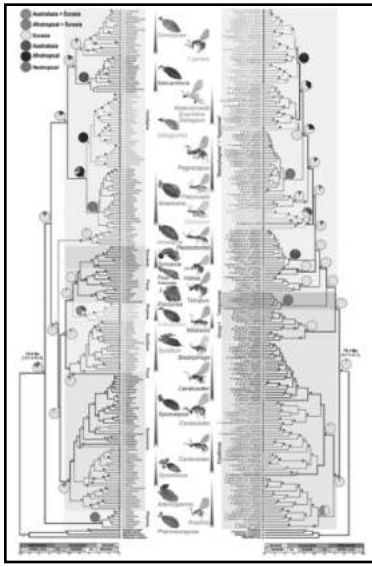


Fig wasps

Figs

19



A 2012 paper showing extreme co-evolution of figs and fig wasps:

Pollination

Fig wasps

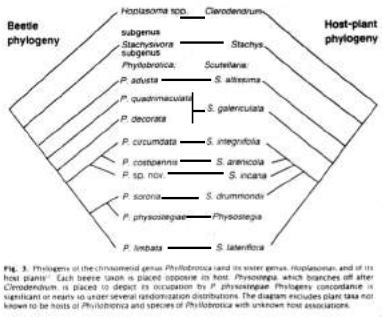
Figs

20

Variation in Lineage Diversity

Flowering plants show remarkable ability to co-evolve with other organisms:

Chemical arm' s race

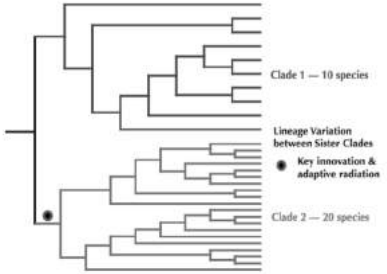


Phyllobrotica

21

Variation in Lineage Diversity

Variation in lineage diversity relates to the appearance of unequal numbers of species in sister lineages



3. Adaptive radiation

One lineage (clade 2) **is more diverse due to combination of** species radiation **and** adaptation **into many ecological zones perhaps due to the origin of a** novel **feature –** key innovation

22

Adaptive Radiations

Emergence of flowering plants has two important facets:

1. Radiation - large number of species resulted
2. Adaptive - exploited incredible array of ecological strategies or niches

23

Adaptive Radiations

• in 130 my, angiosperms dominate biomes from tropical forests to arctic tundra . . .

24

Adaptive Radiations

• . . . rainfall gradients from the wettest to the most arid habitats on earth . . .

25

Adaptive Radiations

• . . . life forms from giant emergent tropical trees to the tiniest aquatic duckweeds . . .

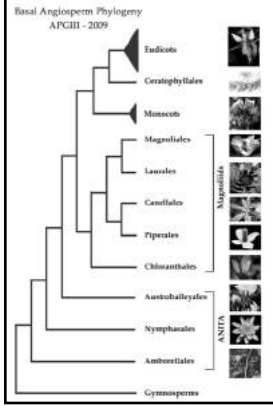
26

Adaptive Radiations

• . . . and exploited reproductive biology in elaborate outcrossing and seed dispersal methods to forgoing sex altogether via apomixis and parthenogenesis

27

Adaptive Radiations

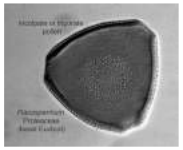


• **Angiosperms show all necessary characteristics of an adaptive radiation**

• Key innovation(s) **spurring this adaptive radiation?**

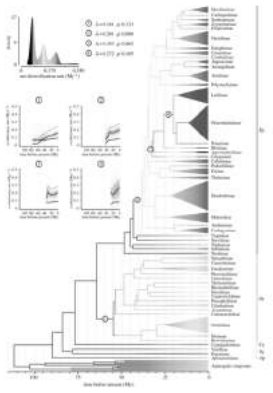
flowers? triaperturate pollen?

vessels? whole genome duplications?



28

Adaptive Radiations



- **Orchids show all necessary characteristics of an adaptive radiation**
- Key innovation(s) **spurring this adaptive radiation?**



Givnish et al. (2015) – read!

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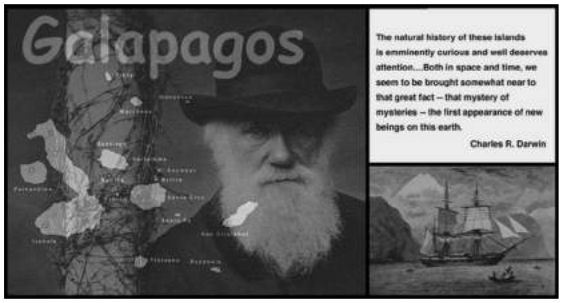
Adaptive Radiations

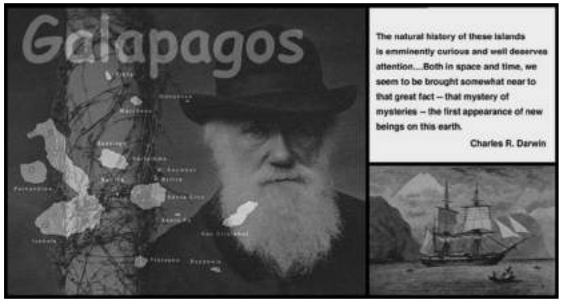
a defintion?



30

Adaptive Radiations

". . . species occasionally arriving after long intervals in a new and isolated district, and having to compete with new associates, will be eminently liable to modification, and will often produce groups of modified descendants" [Darwin, 1859]



31

Adaptive Radiations

". . . an isolated region, if large and sufficiently varied in its topography, soil, climate and vegetation, will give rise to a diversified fauna according to the *law of adaptive radiation* from primitive and central types. Branches will spring off in all directions to take advantage of every possible opportunity of securing food." [Henry Osborn, 1900]

First use of term
adaptive radiation

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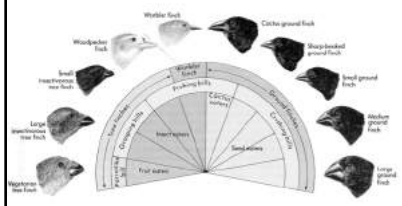
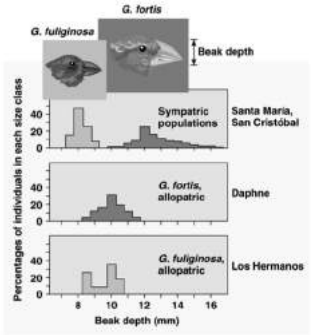
Issues in Adaptive Radiations

• It is clear that few of the classic cases of adaptive radiation had been studied rigorously from a combined systematic and ecological point of view

Two main issues:





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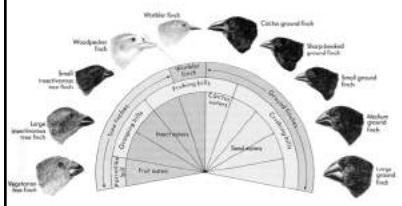
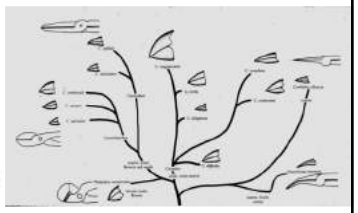
Issues in Adaptive Radiations

1. **The very characters whose diversification is being examined (e.g. beak size, shape, function in Darwin's finches), also were used to determine relationships of and classify the organisms possessing them -** potentially circular!





34

Issues in Adaptive Radiations

2. **Extreme convergence and divergence is likely in groups that are undergoing adaptive radiations**

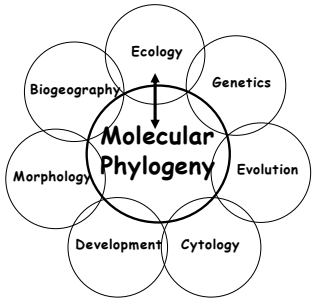
Divergence: **changes in homologous structures** among related species; **changes permit each species to specialize in different environments**

Convergence: **changes in analogous structures** among unrelated species; **changes permit each species to specialize in the same environment**

35

Issues in Adaptive Radiations

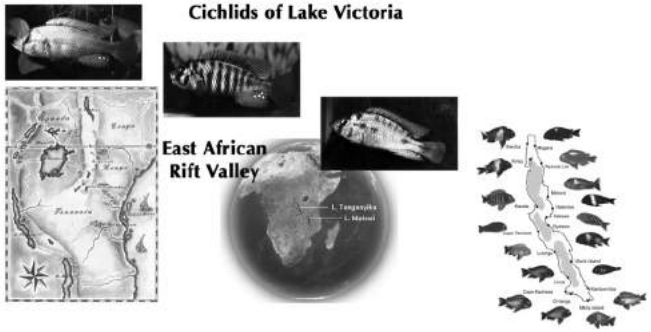
These two issues in studying adaptive radiations are best addressed by using an independent source of information **- molecular phylogenetic characters**



36

Adaptive Radiations

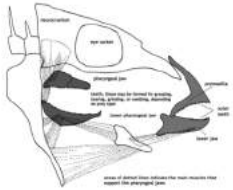
Illustration of these problems with 2 examples of adaptive radiation – African cichlid fishes and Hawaiian lobeliads



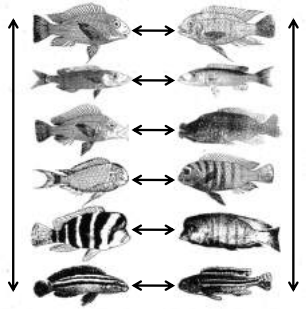
37

Rift Valley Cichlids

Cichlids possess a double jaw system, the pharyngeal jaw **is thought to be a** key innovation **for species proliferation and divergence in feeding strategies**



- **species with similar feeding strategies** between lakes related**?**
- **species showing different feeding strategies** within a lake related**?**

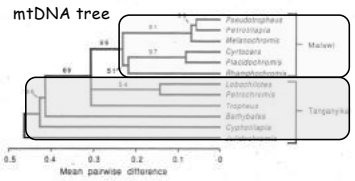


Lake Tanganyika Lake Malawi

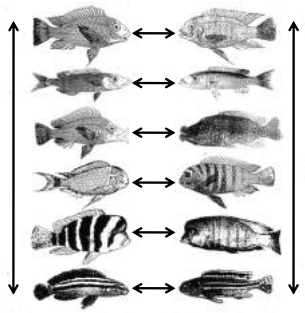
38

Rift Valley Cichlids

Cichlids possess a double jaw system, the pharyngeal jaw **is thought to be a key innovation for species proliferation and divergence in feeding strategies**



- **Species** within each lake **related!**
- divergence within each lake!
- convergence between lakes!



Lake Tanganyika Lake Malawi

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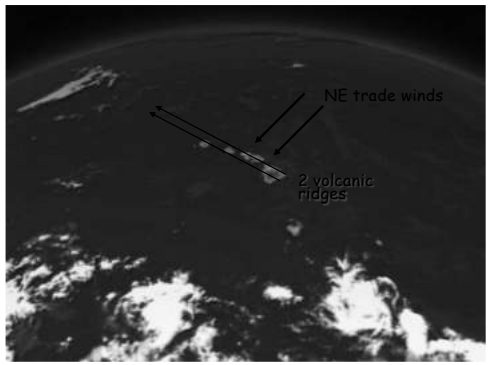
Hawaiian Island Radiations

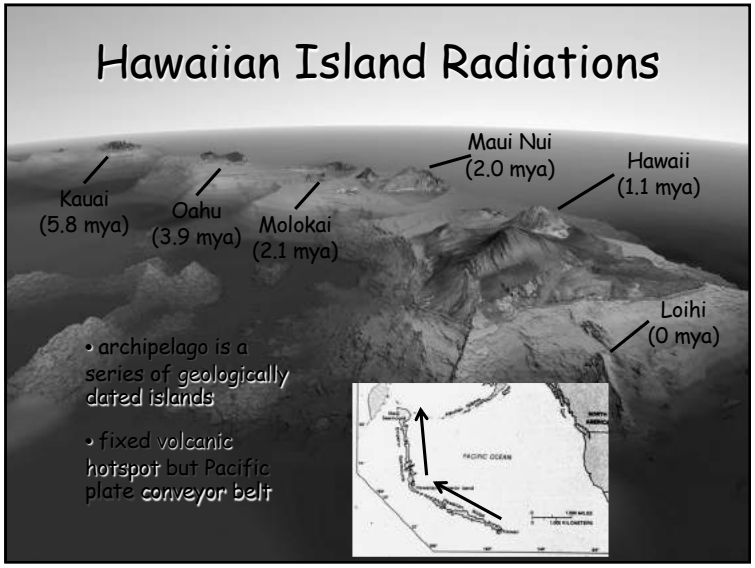
Isolated, oceanic islands provide some of the most classic examples of adaptive radiation



- isolation - **once you get there, you can't go back**
- great ecological diversity - **many niches to exploit**
- low diversity - **many niches open**
- low competition, predation, herbivory - **you can be different**

40

Hawaiian Island Radiations



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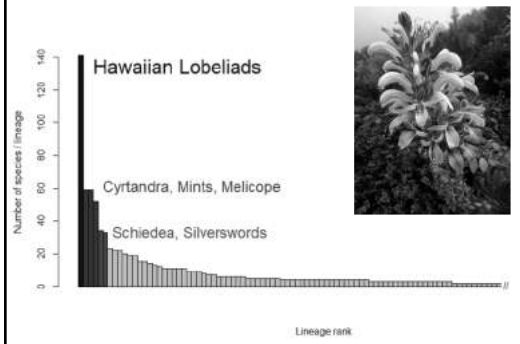
Hawaiian Lobeliads

Why the Hawaiian lobeliads?



- largest group: **6 genera, 140 species**
- 1/8th **of native flora**

42

Hawaiian Lobeliads

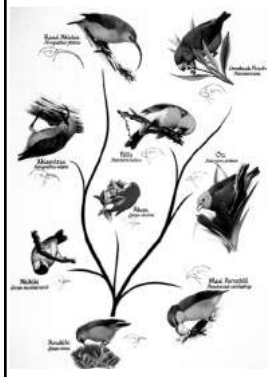
Why the Hawaiian lobeliads?

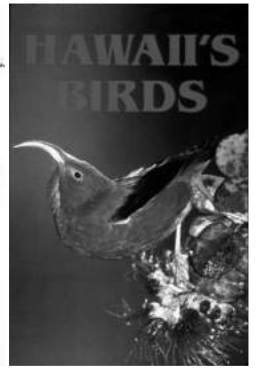
- largest group: **6 genera, 140 species**
- 1/8th **of native flora**
- phenomenal variation **in habitat, life form, flowers, and fruits**
- **considered derived from** 3-5 separate colonizations

43

Hawaiian Lobeliads

Why the Hawaiian lobeliads?



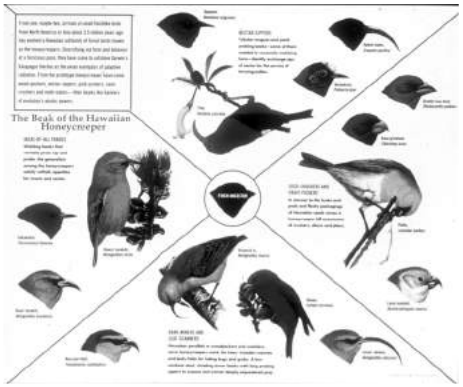


- **appear to have** co-evolved **with the endemic** Hawaiian honeycreepers

44

Hawaiian Lobeliads

Why the Hawaiian lobeliads?



- **appear to have** co-evolved **with the endemic** Hawaiian honeycreepers
- **honeycreepers represent a separate adaptive radiation**

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Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Lobelia gloria-montis

Lobelia telekii - Mt. Kenya

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Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Brighamia

47

Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Delissia

48

Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Trematolobelia

49

Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Clermontia

50

Hawaiian Lobeliads

What are the Hawaiian lobeliads?

Cyanea

51

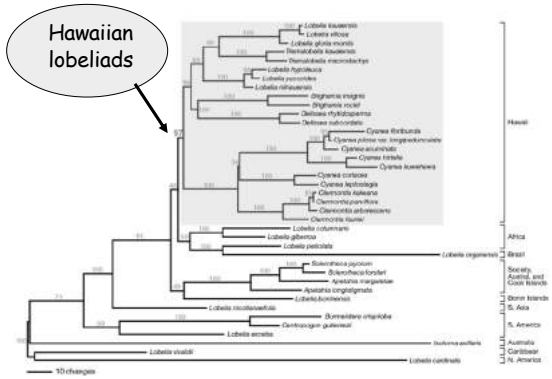
Hawaiian Lobeliads

- sequenced over 6 million base pairs of DNA in each of about 100 species – to test for "finger print" of ancestry

Dr. Steve Hunter

52

Hawaiian Lobeliads



- DNA supports common ancestry of ALL Hawaiian lobeliads – one single ancestral seed dispersed to Hawaii & radiated into the more than 140 species

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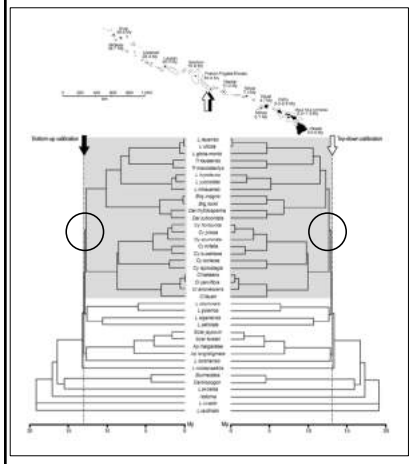
Hawaiian Lobeliads



Two clock calibrations - using Asterid fossils or using Hawaiian Island ages - place the differentiation of Hawaiian lobeliads at 13-14 mya

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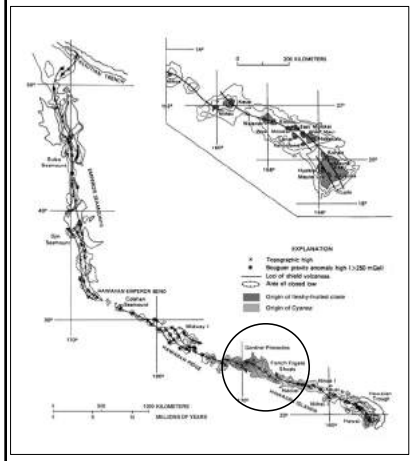
Hawaiian Lobeliads



Two clock calibrations - using Asterid fossils or using Hawaiian Island ages - place the differentiation of Hawaiian lobeliads at 13-14 mya

Original colonist arrived in Gardner Pinnacles or French Frigate Shoals - **large volcanic islands 12-16 mya**

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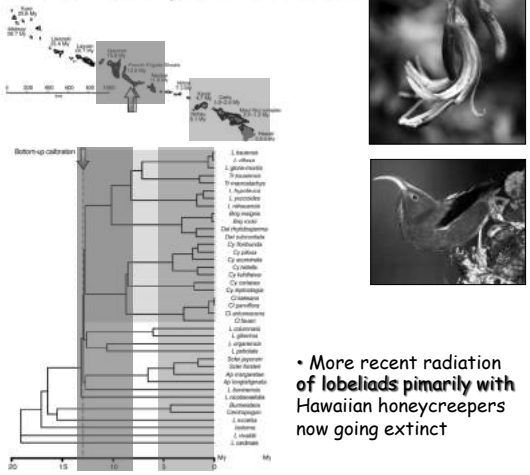
Hawaiian Lobeliads



- Early lobeliads **had initial radiation with** Hawaiian honeyeaters now extinct

- More recent radiation **of lobeliads pimarily with** Hawaiian honeycreepers now going extinct

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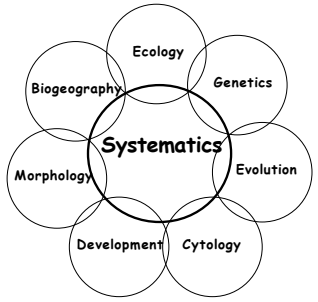
Future of Systematics



. . . it is central to biological sciences!

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Concluding thoughts . . .

The field of plant systematics epitomizes the work of all other branches of biology centered on the organism itself, and brings the varied factual information from them to bear on the problems of interrelationships, classification, and evolution.

Thus, systematics is at once the alpha and omega of biology.

Reed Rollins 1957

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Concluding thoughts . . .

Plant systematics has not outlived its usefulness; it is just getting under way on an attractively infinite task.

Lincoln Constance, 1957

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