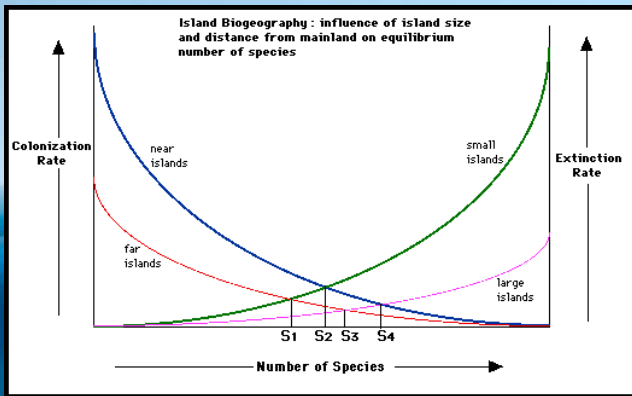


Biogeography of Hawaii



Island biogeography



Dispersal

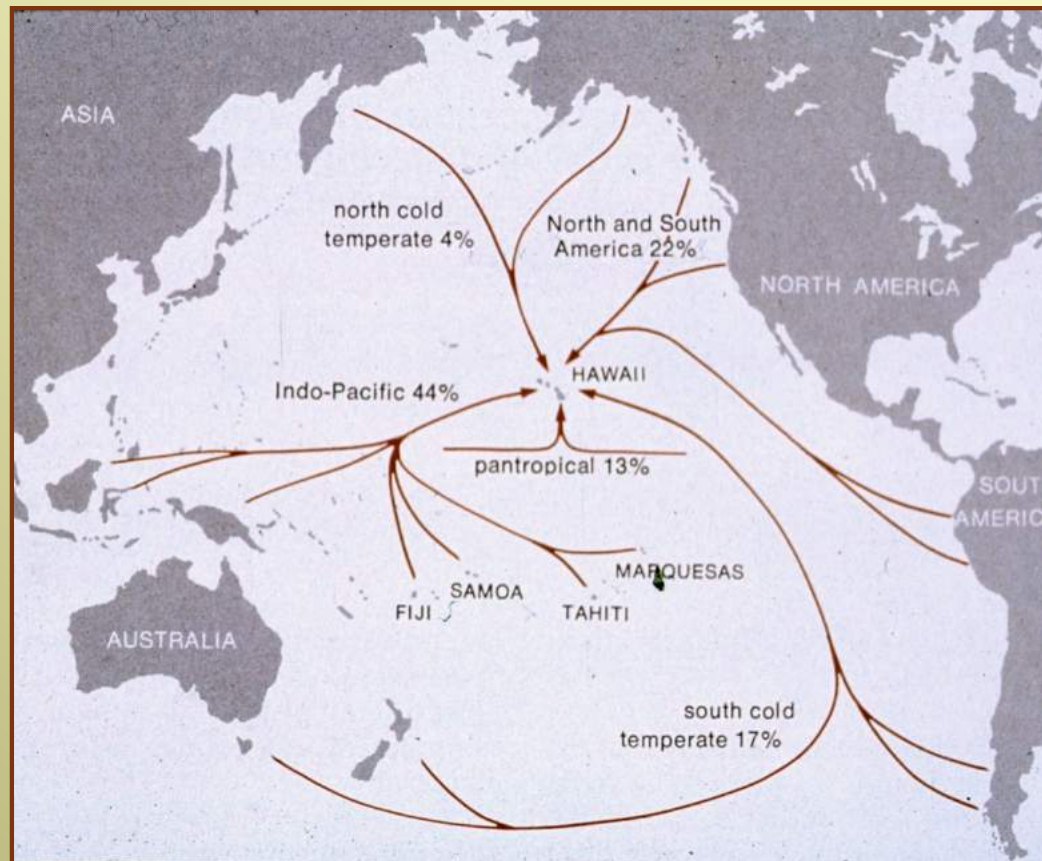


Adaptive radiations

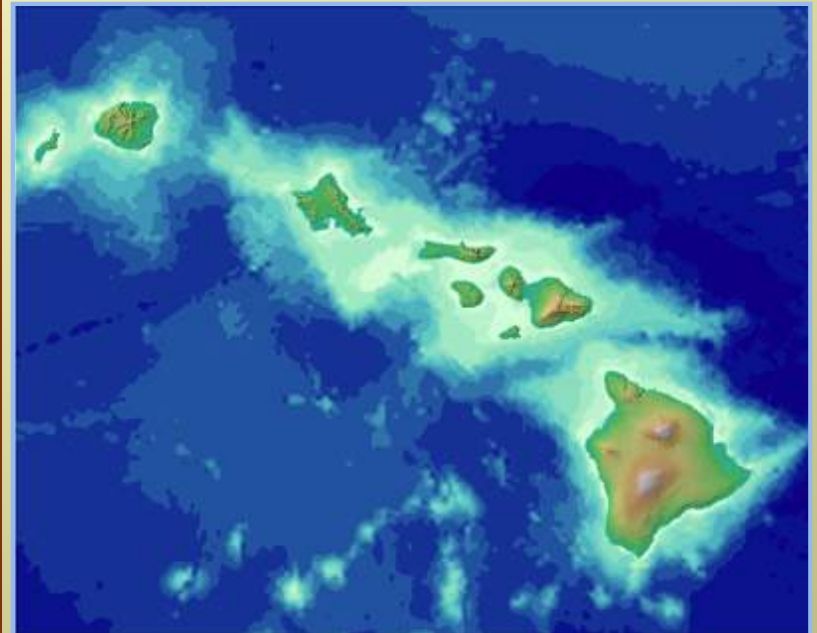
We will integrate all three island phenomena in the context of the Hawaiian Islands

Hawaiian archipelago - *the example* for island biogeography

“Getting there is half the problem . . . but then they can’t go home again”



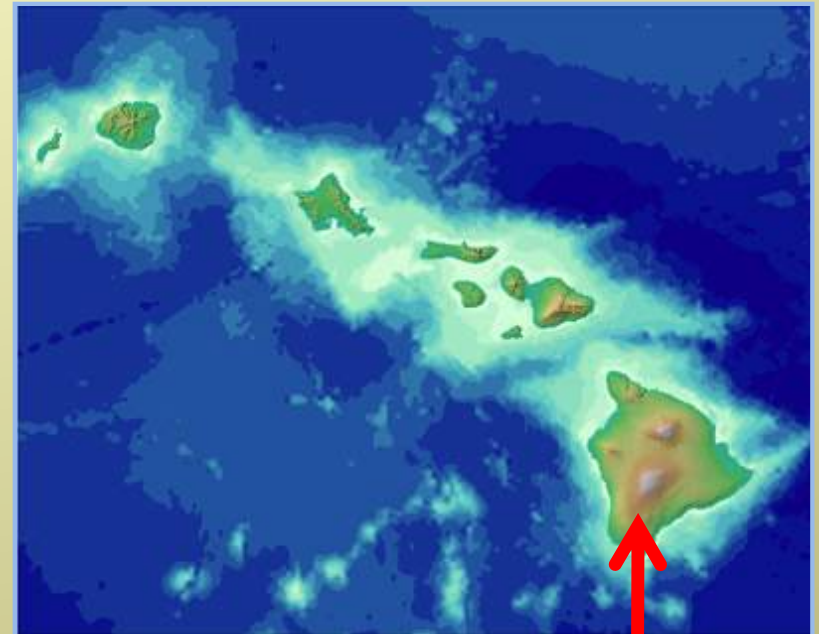
Sherwin Carlquist, 1965



Hawaiian archipelago - *the example* for island biogeography

*“If one were to stand at the top of Mauna Loa, he could see
all the climes of the world at a single glance of the eye”*

Mark Twain, 1866

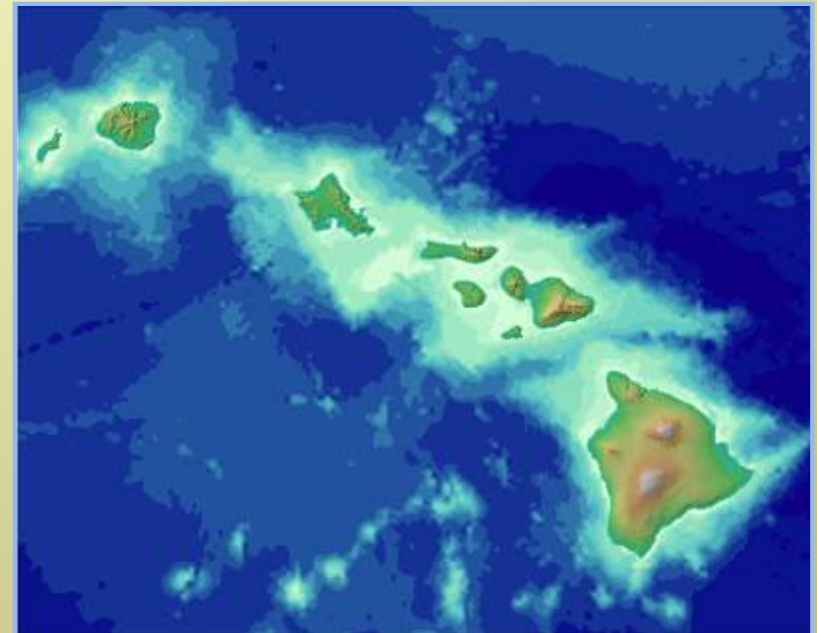
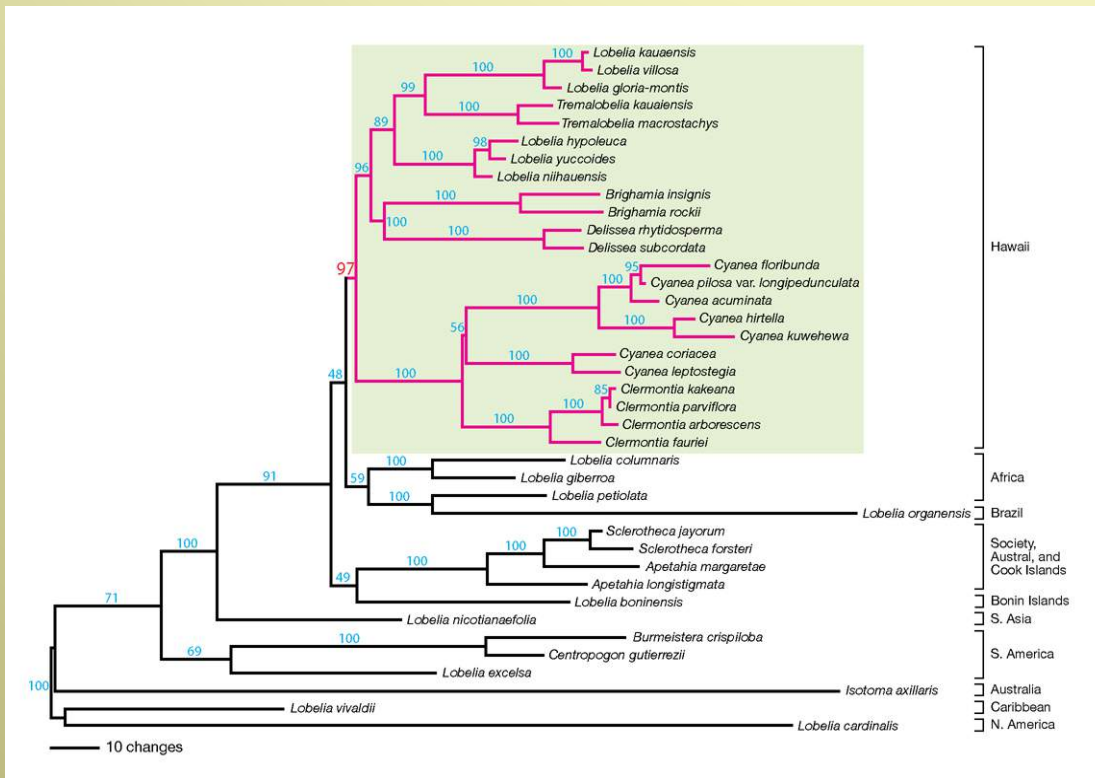


4,169 m OR 13,679 ft

Hawaiian archipelago - *the example* for island biogeography

“Assume nothing in Hawaiian natural history”

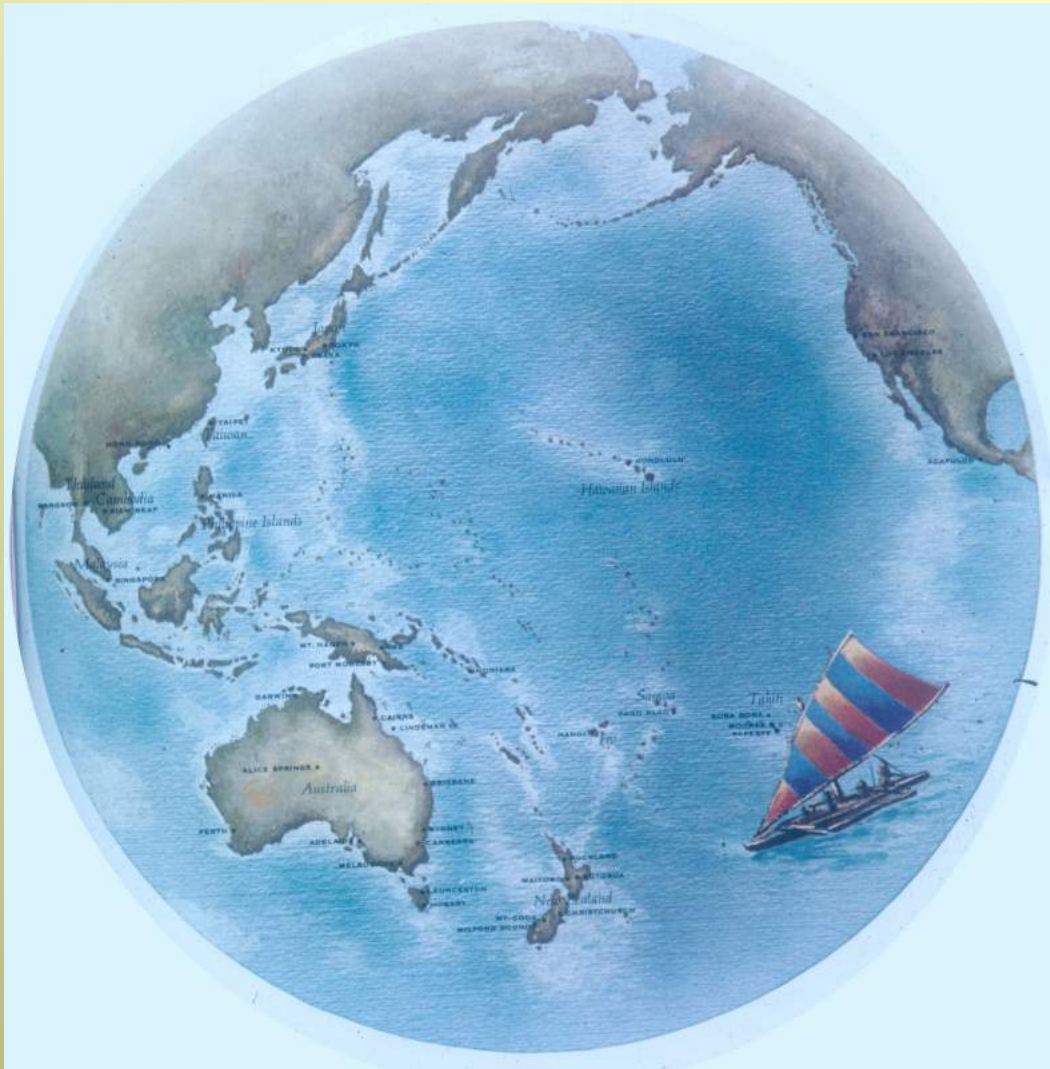
Frank Howarth, 1992



Hawaiian archipelago - *the example* for island biogeography

Most remote island system in the world

- settled in 1st millenium by Polynesians
- made known to science by Captain Cook in 1778



Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa



- around 1,000 species of flowering plants
- 225 species of ferns and allies



Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- nearly 5,800 species of insects
- 130 species of spiders



Happyface spider



Kamehameha butterfly

Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- 230 species of birds
- 800 species of terrestrial molluscs



Kauai O' o



Land snails

Hawaiian Biota

Hawaiian biota: most are found nowhere else in the world and exhibit traits uncharacteristic of their taxa

- no amphibians
- no terrestrial mammals



Hawaiian hoary bat



Hawaiian monk seal

Hawaiian Biota

Hawaiian biota: **extinction** on-going process both in past and present



Hawaiian hoary bat

- arrived 10,000 years ago



Extinct small Hawaiian bat

- arrived 320,000 years ago
- extinct 1,100 years ago

Hawaiian Biota

Hawaiian biota: **extinction** on-going process both in past and present



Extinct snail, flightless duck, lobeliad



from left to right
Kauai O'O Extinct, Kauai Akialoa Extinct, O'u Extinct,
Kauai Nukupu'u Extinct, Puaiohi less then 200 remain, Kamao Extinct

Hawaiian honeycreepers

Hawaiian Archipelago

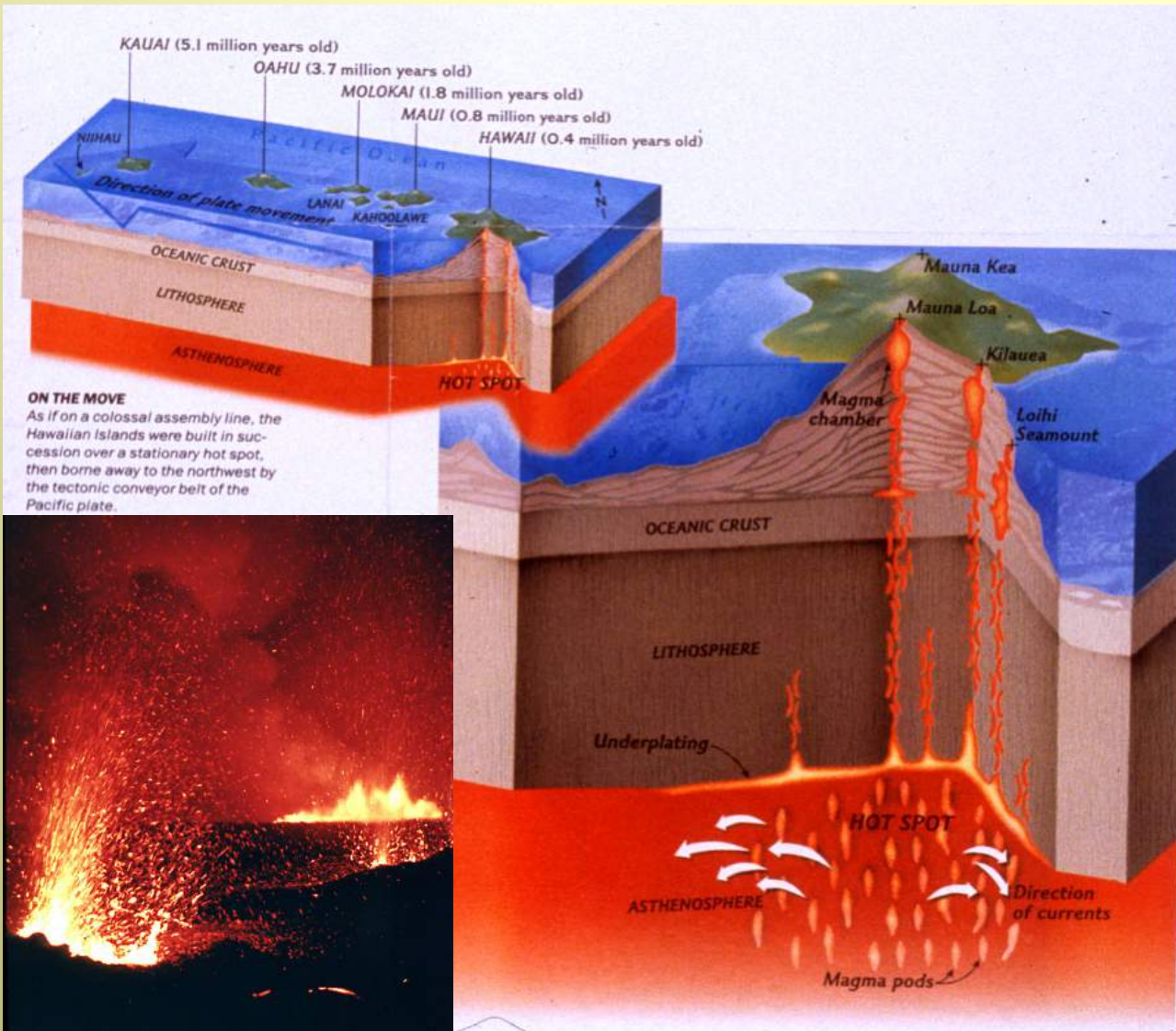


- 99% of land lies on 8 main islands near the **hot spot** below Lo' ihi

- 132 islands, reefs, & shoals
- 2,580 km on SE-NW line

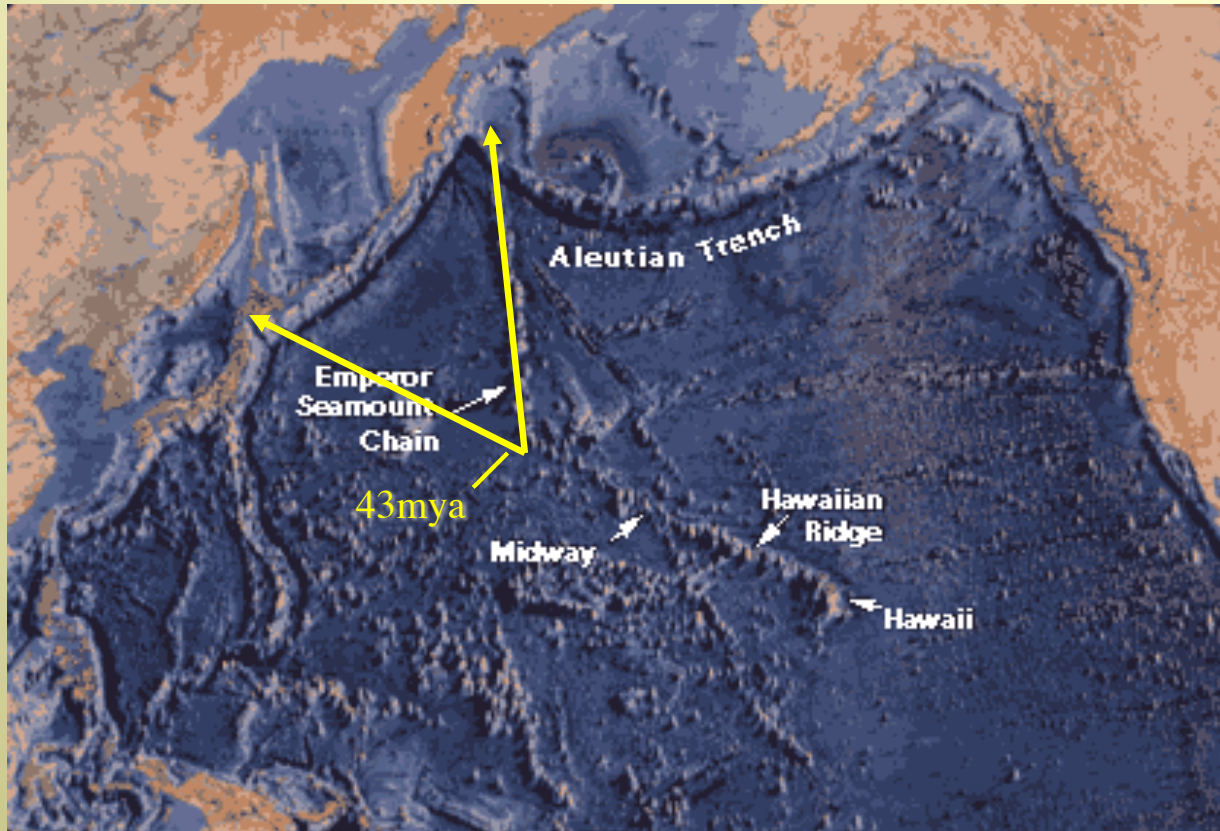


Hawaiian Archipelago



- hot spot stationary relative to Pacific Plate motion
- forms hot spot trace
- potassium-argon dating indicates oldest islands furthest from hot spot
- newest island Loihi still underwater - seamount

Hawaiian Archipelago



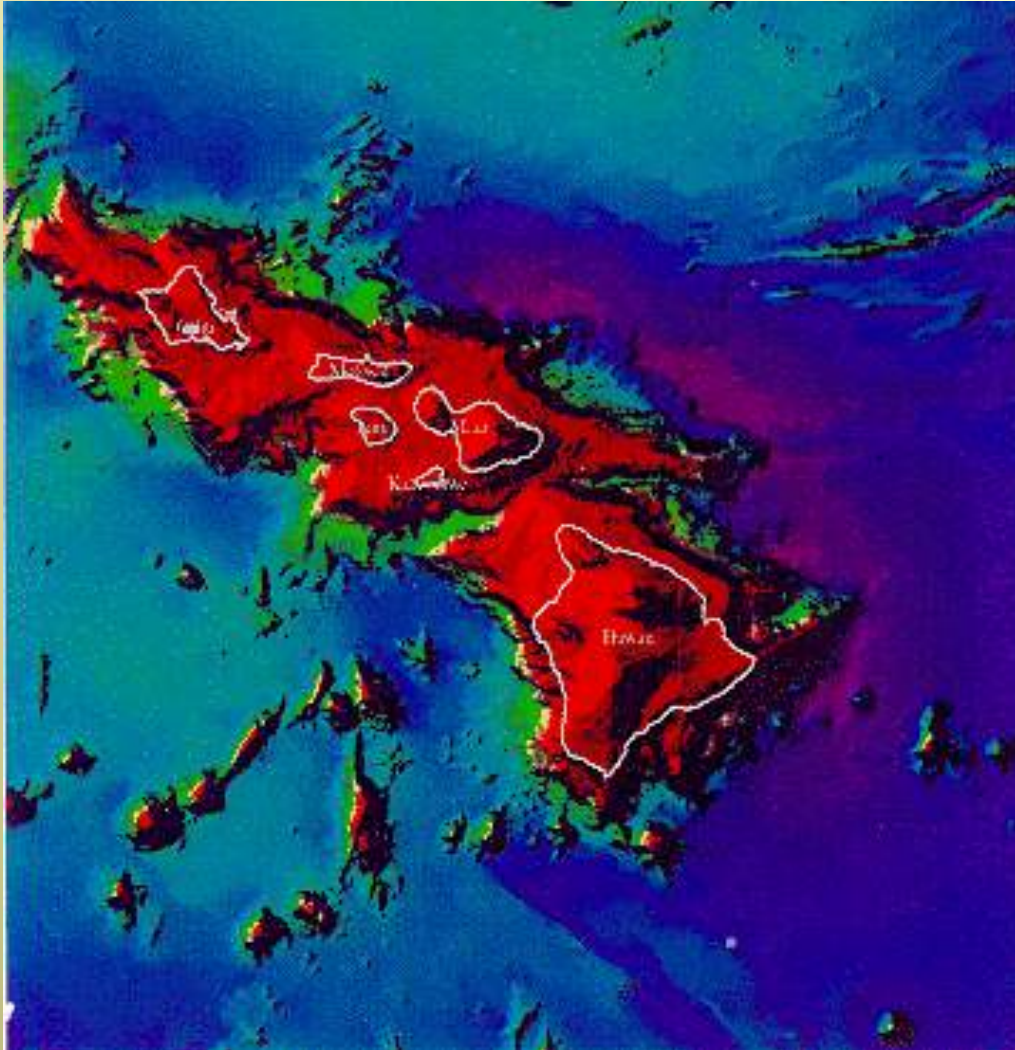
- plate motion changed 43 mya
- oldest seamounts subducted into Aleutian Trench

Hawaiian Archipelago

- Islands (and shoals) are simply emergent tops of great underwater volcanoes
- up to 10km above ocean floor

Mauna Kea – 10.2 km (4.2 km)

Mauna Loa - 37 m lower but most massive



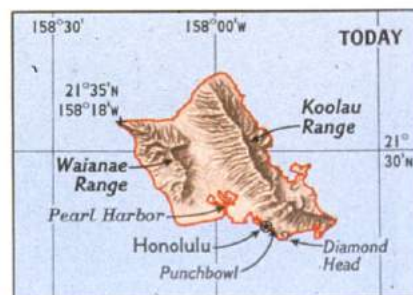
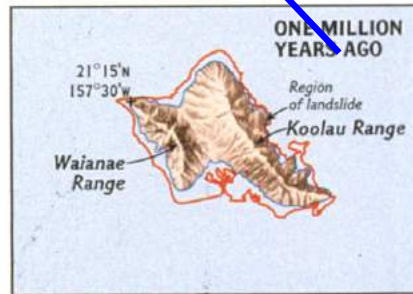
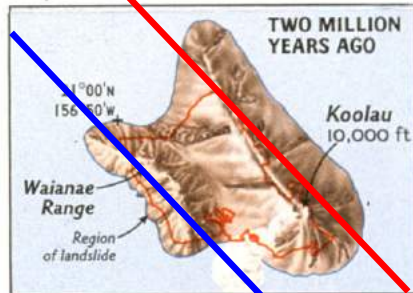
USGS 'GLORIA' side sonar



Mauna Loa

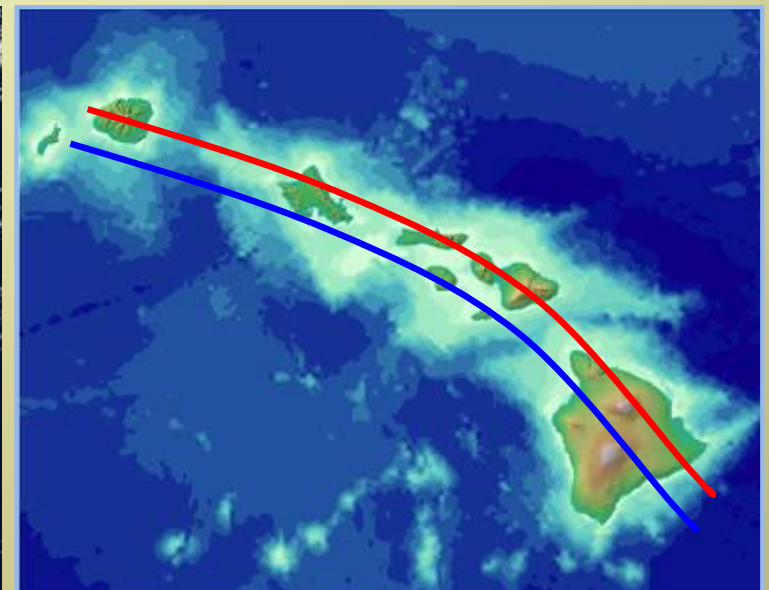
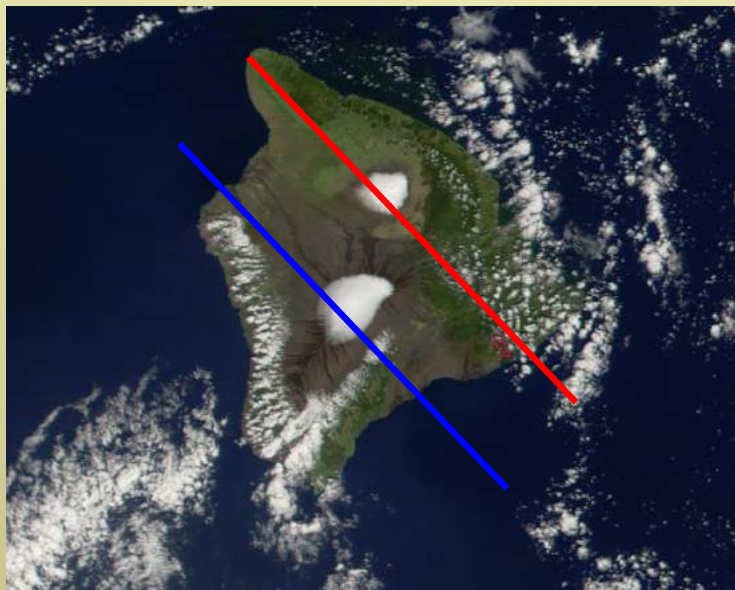
Hawaiian Archipelago

- actually double hot spot 30km apart
- Lo' ihi to Mauna Loa
- Kilauea to Mauna Kea



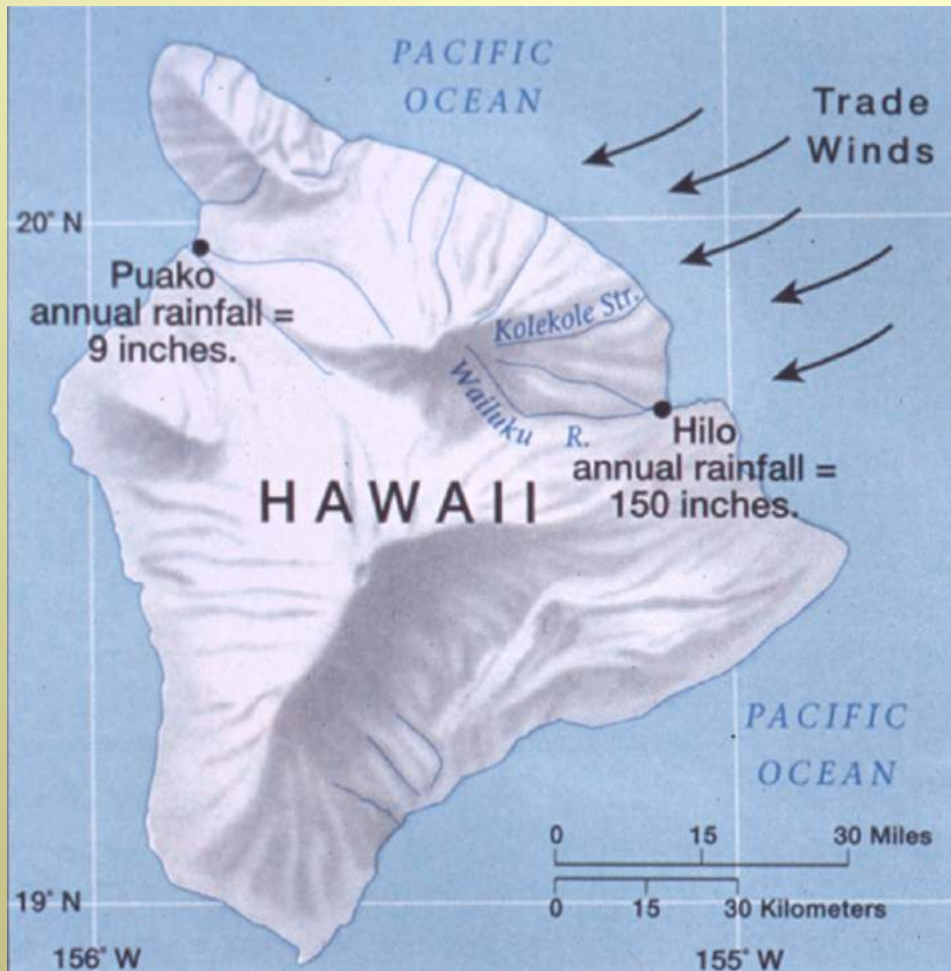
Oahu

Hawaii



Hawaiian Climate

- primary weather pattern is northeasterly trade winds
- severe kona winds come from leeward side

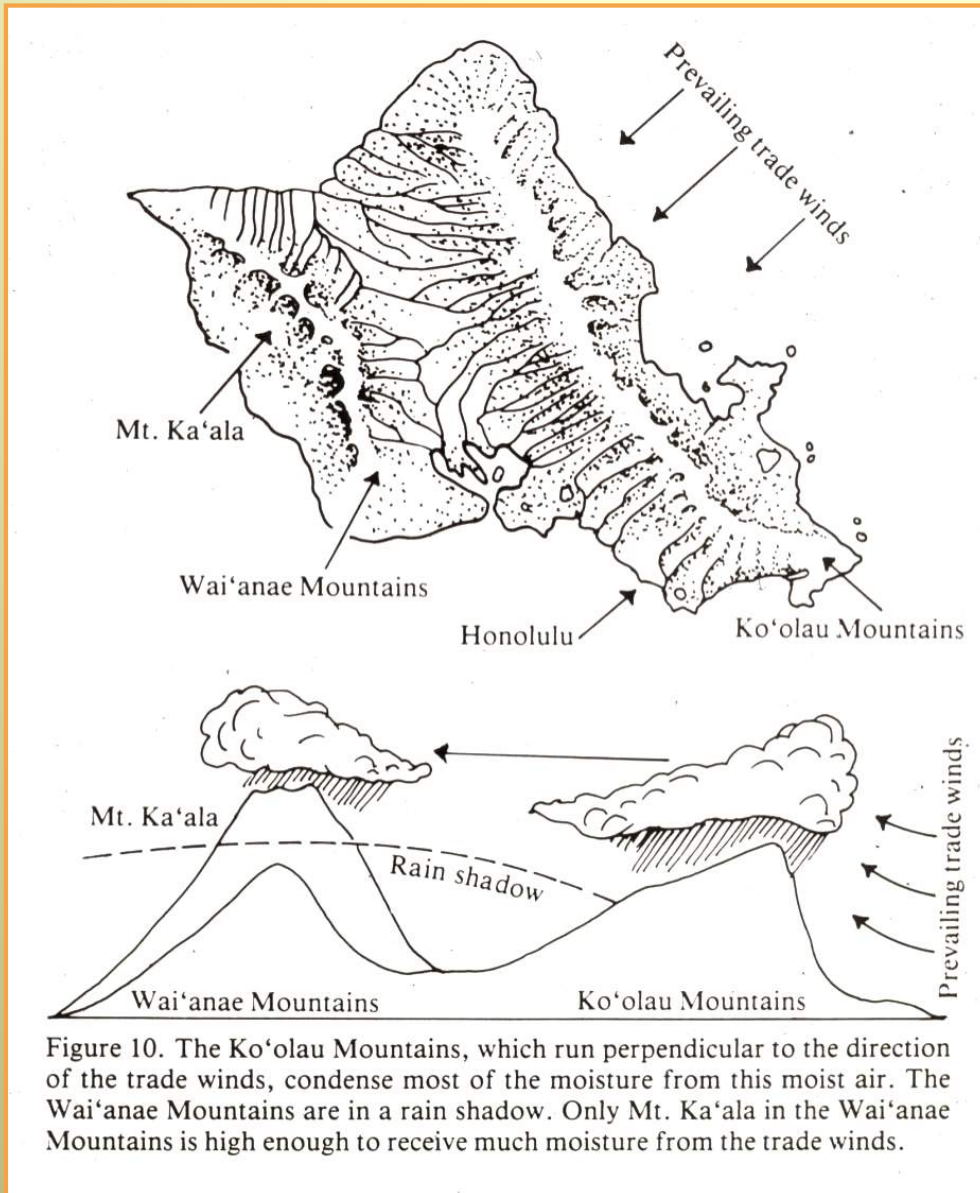


Hilo (windward and wet) vs. Kona Coast in Hawaii (leeward and dry)

Hawaiian Climate

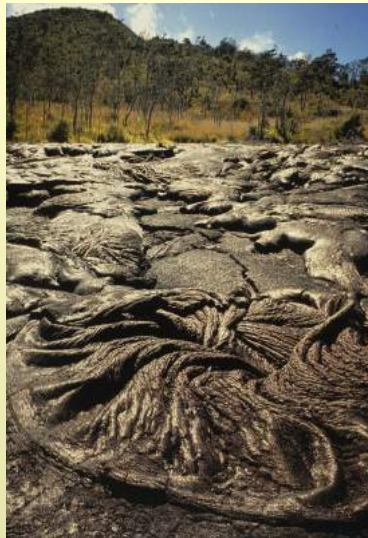
rainfall patterns

- double mountain system (as in Oahu) sets up complex rainfall gradient and a diversity of ecosystems



Hawaiian Climate

- extraordinary rich and **diverse** habitats available
- 38 community types recognized



Hawaiian Climate

rainfall patterns

- Wai'ale'ale on oldest (most eroded) island of Kauai is wettest spot in Hawaii and possibly in the world



- 11.5 m of rain and presence of the Alakai Swamp



Hawaiian Climate

rainfall patterns

- Pu'ukukui (5,788 ft) on west Maui is 2nd wettest spot; xeric summit of Haleakala on east Maui is 10,023 ft



Greensword bog - west Maui

Flora of Hawaii

*“Assume nothing in Hawaiian
natural history”*

Flora of Hawaii

- since so isolated, it has a **depauperate** flora and consists entirely of **waif** elements derived from LDD

native



Argyroxiphium sandwicense - Haleakala silversword

MANUAL OF THE
FLOWERING PLANTS
OF
HAWAI'I
VOLUME I



WARREN L. WAGNER DERRAL R. HERBST
S. H. SOHMER

or weeds



Passiflora mollissima - Banana poka

Flora of Hawaii

- individual islands tend to fit the expected number of species based on area
 - except most recent Hawaii

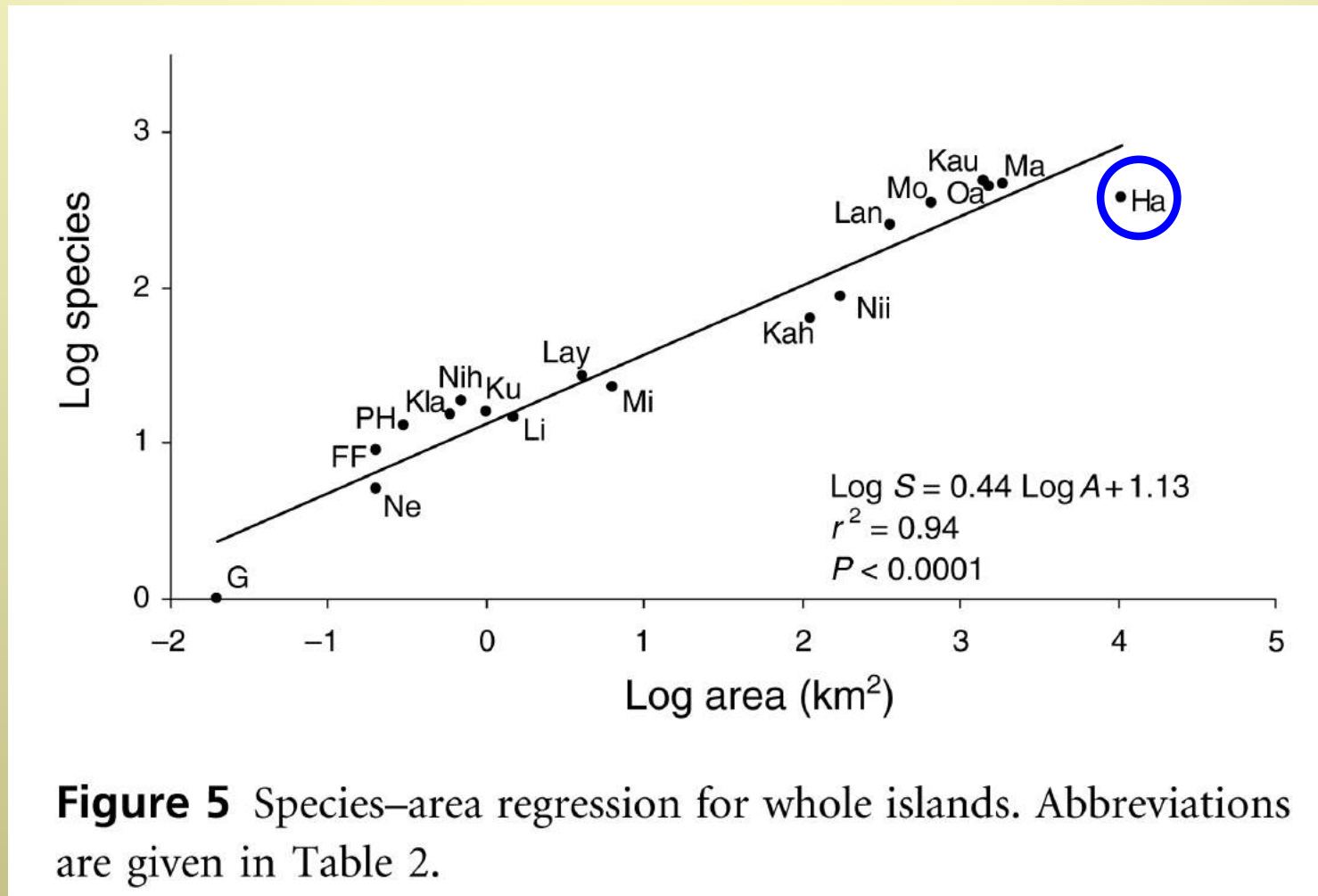


Figure 5 Species–area regression for whole islands. Abbreviations are given in Table 2.

Flora of Hawaii

- **endemism** high in flowering plants (highest in world)

956 native species

- 89% endemic

216 native genera

- 15% endemic

87 native families

- 0% endemic

1,817 including introduced

649 including introduced

146 including introduced



Flora of Hawaii

- disharmonic flora



- only 3 native orchid species



- but many introduced orchids that become naturalized

Dendrobium & honey bees

Flora of Hawaii

- disharmonic flora



- only 1 native palm genus (coconut?)
- native gymnosperms and primitive angiosperms absent



Pritchardia beccariana

Flora of Hawaii

- disharmonic flora - 15 largest families of native species

Campanulaceae 110

Asteraceae 92

Rutaceae 55

Lamiaceae 54

Rubiaceae 54

Gesneriaceae 53

Poaceae 47

Cyperaceae 45

Caryophyllaceae 33

Piperaceae 25

Malvaceae 24

Euphorbiaceae 21

Fabaceae 20

Solanaceae 9

Myrtaceae 8



- large source area families under represented

- small Campanulaceae - lobeliads and bellflowers - over represented



Flora of Hawaii

- immigrants: 270 (or less!) gave rise to 956 native angiosperms

TABLE 3. Twenty most speciose genera of Hawaiian flowering plants and presumed numbers of colonists.

Genus	Number of species	Presumed number of colonists
<i>Cyrtandra</i>	53	4-6
<i>Cyanea</i>	52	1
<i>Pelea</i>	47	1
<i>Phyllostegia</i>	27	1
<i>Peperomia</i>	25	3-4
<i>Clermontia</i>	22	—
<i>Schiedea</i>	22	1
<i>Dubautia</i>	21	1
<i>Lipochaeta</i>	20	2 (polyphyletic)
<i>Stenogyne</i>	20	—
<i>Myrsine</i>	20	1-2
<i>Hedyotis</i>	20	1-2
<i>Bidens</i>	19	1
<i>Pritchardia</i>	19	1
<i>Chamaesyce</i>	15	1-2
<i>Labordia</i>	15	1
<i>Sicyos</i>	14	1
<i>Coprosma</i>	13	2
<i>Lobelia</i>	13	2
<i>Wikstroemia</i>	12	1
Totals	469	26-32

- 1/10th of colonist generates 1/2 of species !

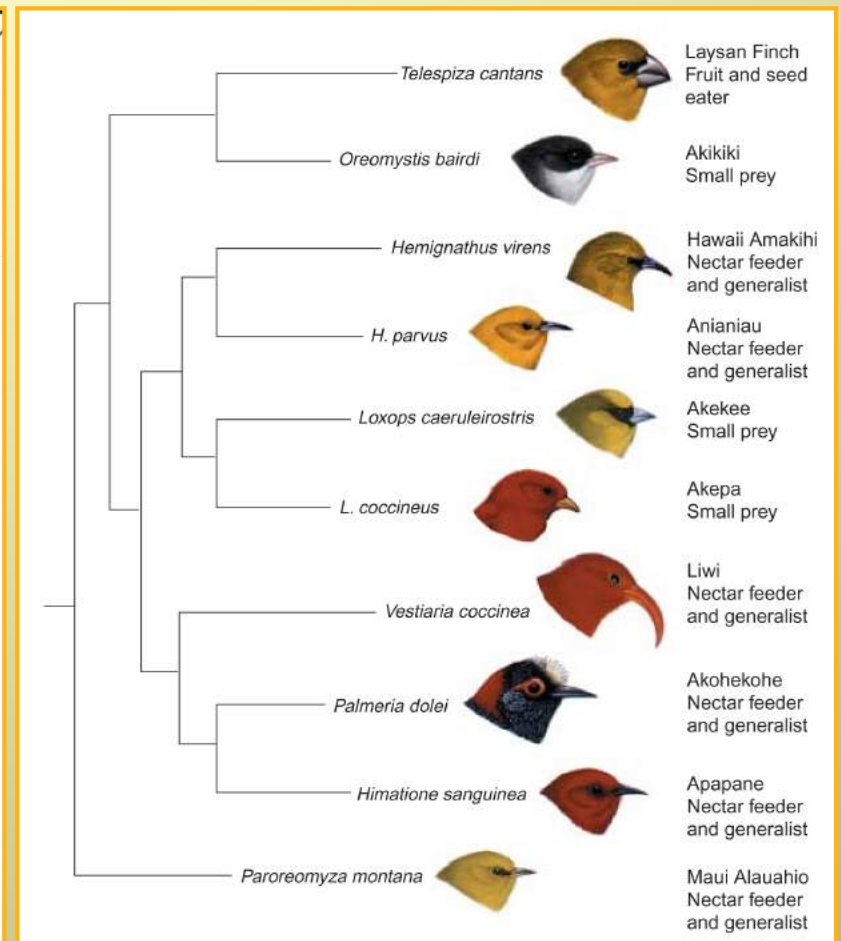
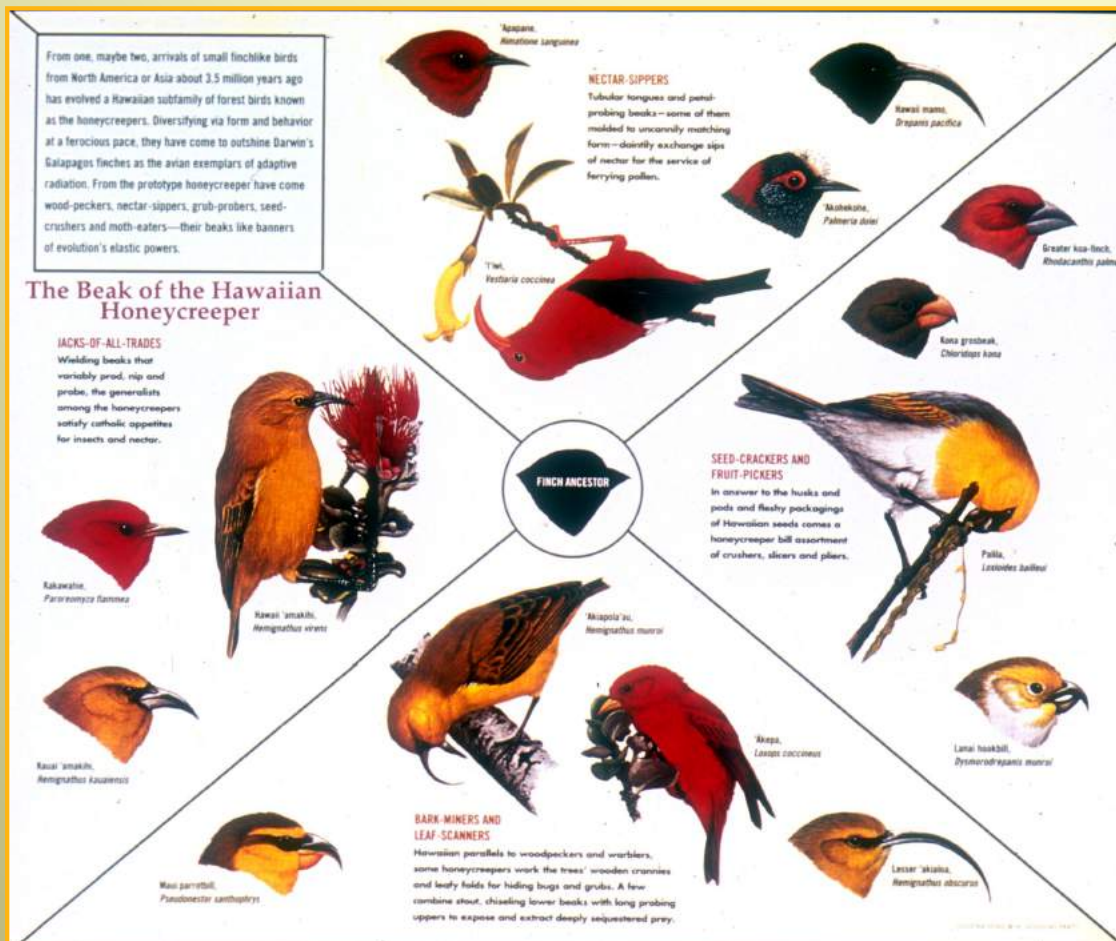
Cyanea

Cyrtandra *Pelea*



Flora of Hawaii

- **immigrants**: similar story with other biota
 - one American finch gave rise to 33 extant and 14 extinct species of honeycreepers



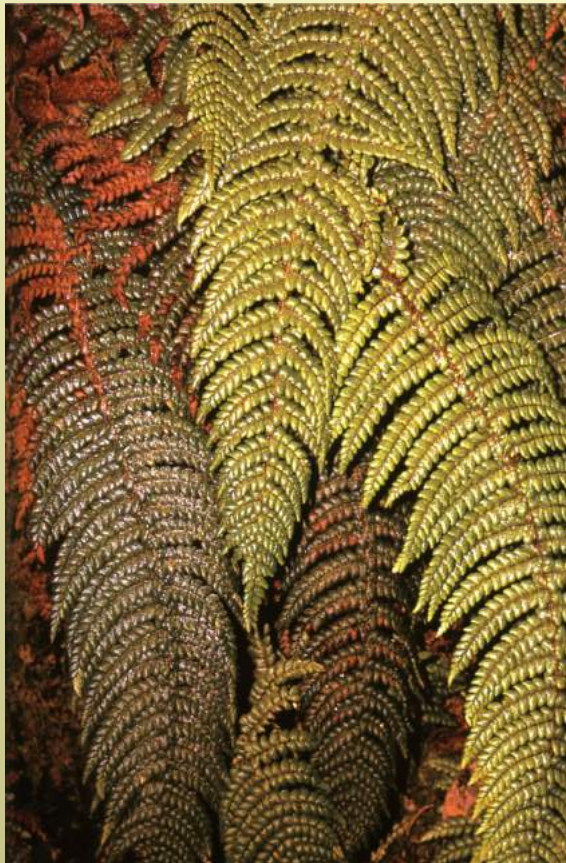
Flora of Hawaii

- **immigrants**: similar story with other biota
 - 800 land molluscs from 20 colonists
 - 5,800 insects from 250 colonists



Flora of Hawaii

- **immigrants**: but different story for ferns!
- 168 ferns from 135 colonists - implying constant immigration (lack of genetic isolation) and/or few speciation events



Sadleria - 6 species

vs.



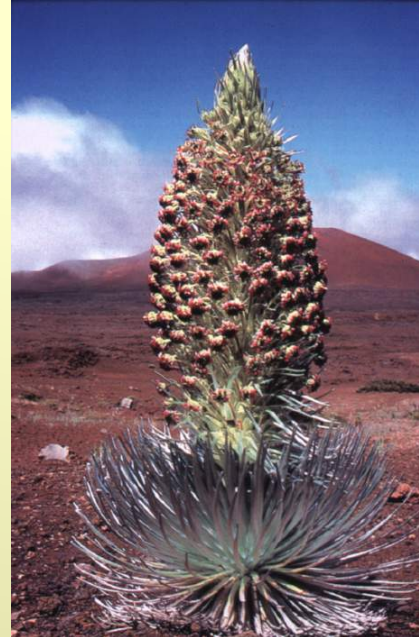
Polypodium - 1 species

Flora of Hawaii

- LDD mechanisms

1%	A	air
39%	BI	internal
13%	BM	mud
10%	BV	viscid
12%	BB	barbs/hooks
14%	DF	drift
9%	DR	drift - rare

74%



Argyroxiphium BB



Leptocophylla BI



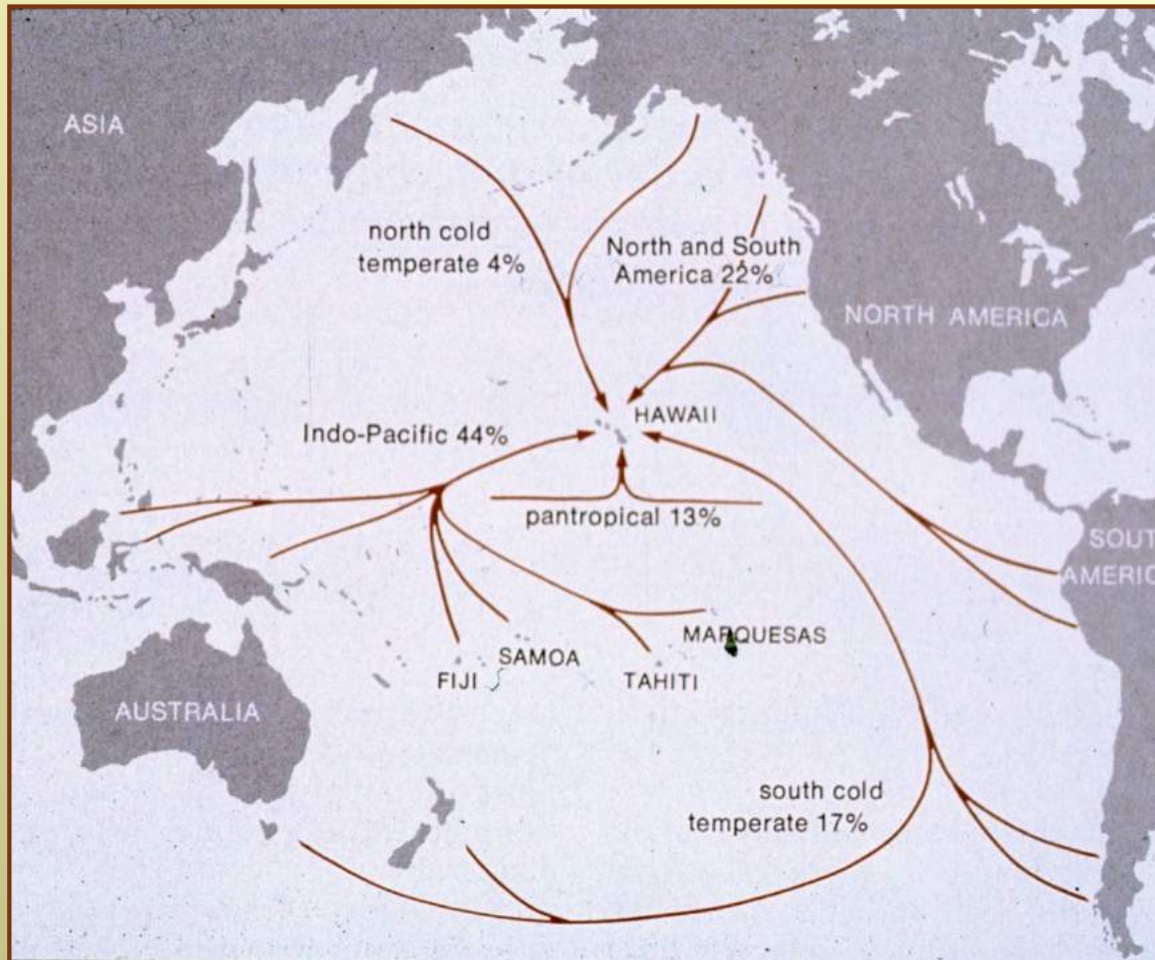
Acacia - koa DR



Viola BM

Flora of Hawaii

- floristic affinities

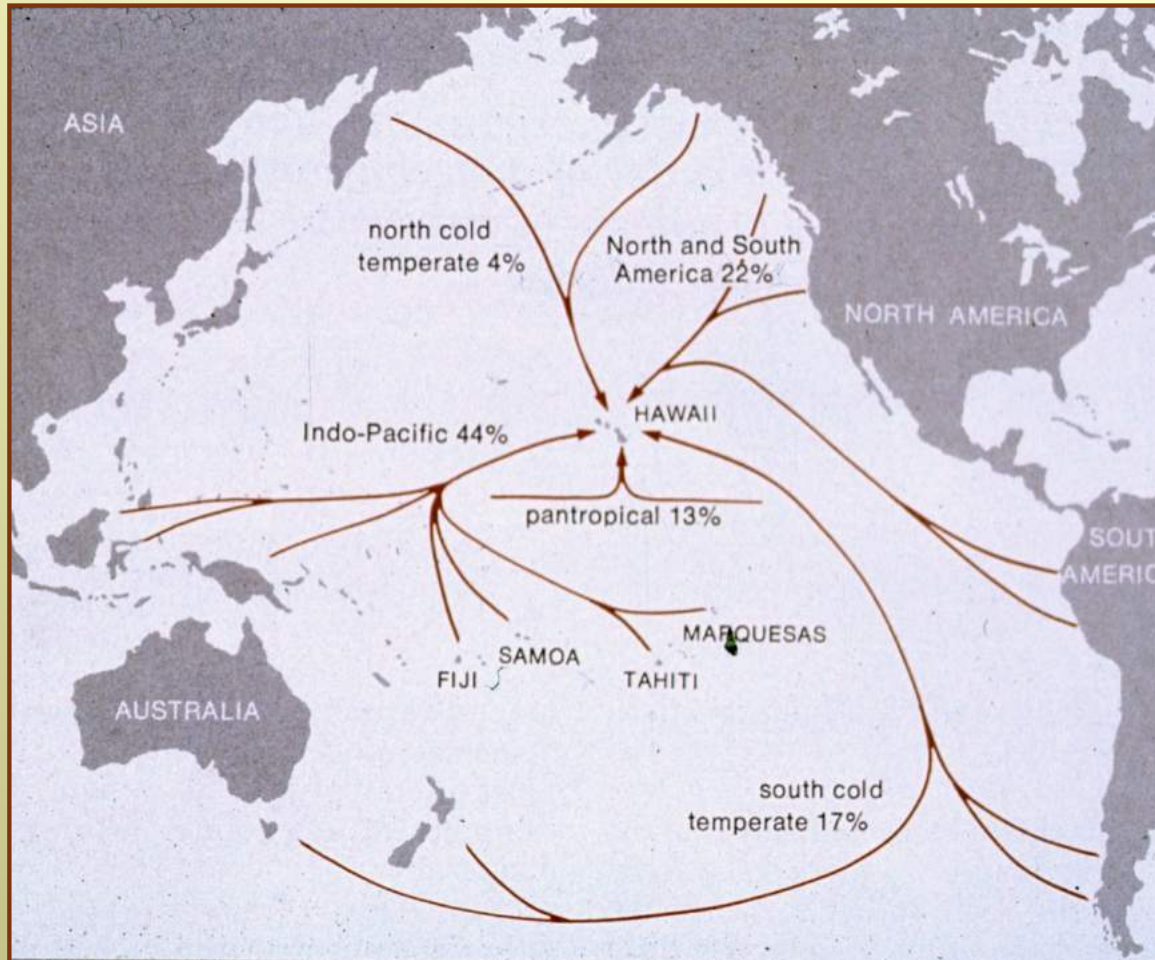


Leptocophylla
Epacridaceae

- despite proximity of Hawaii to N America, almost half of colonists are of Austral-asian origin

Flora of Hawaii

- floristic affinities



Viola

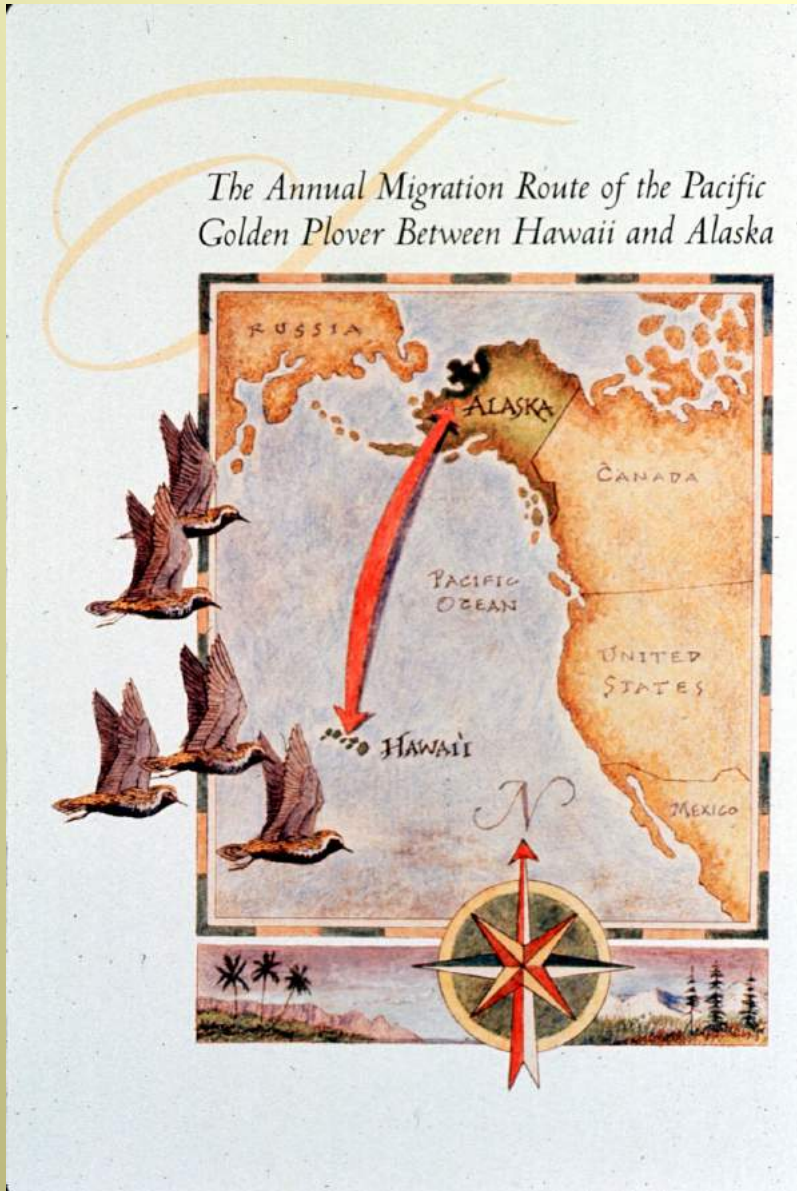
- few from Arctic-Beringia



Plantago - plantain

Flora of Hawaii

- floristic affinities



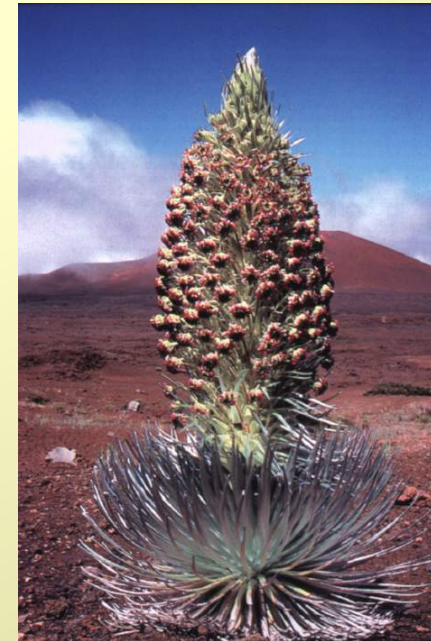
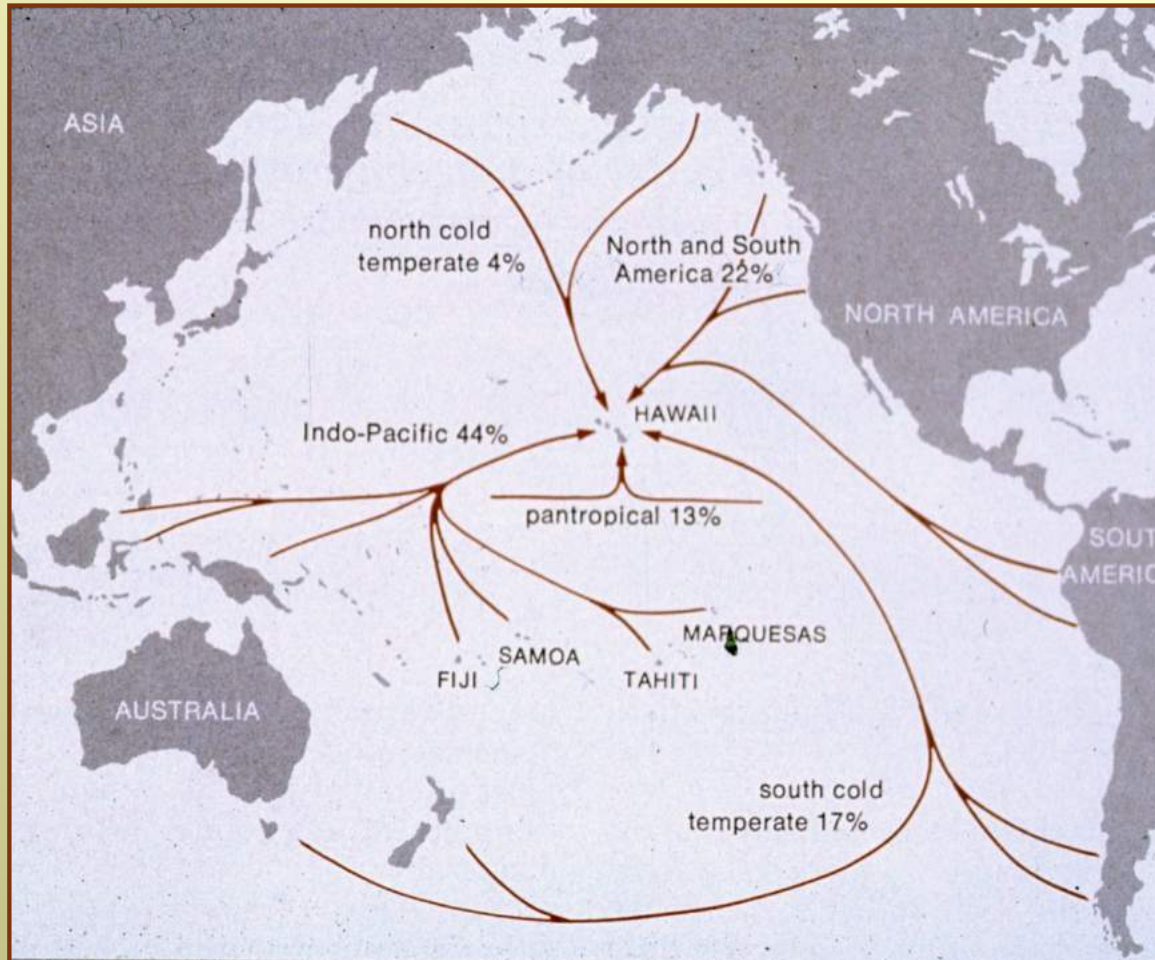
Viola

Viola langsdorfii

- woody violets *once* considered closely related to South American violets
- all native Hawaiian violets are polyploid and derived from polyploid races of one Beringian tundra species - the Alaskan violet

Flora of Hawaii

- floristic affinities

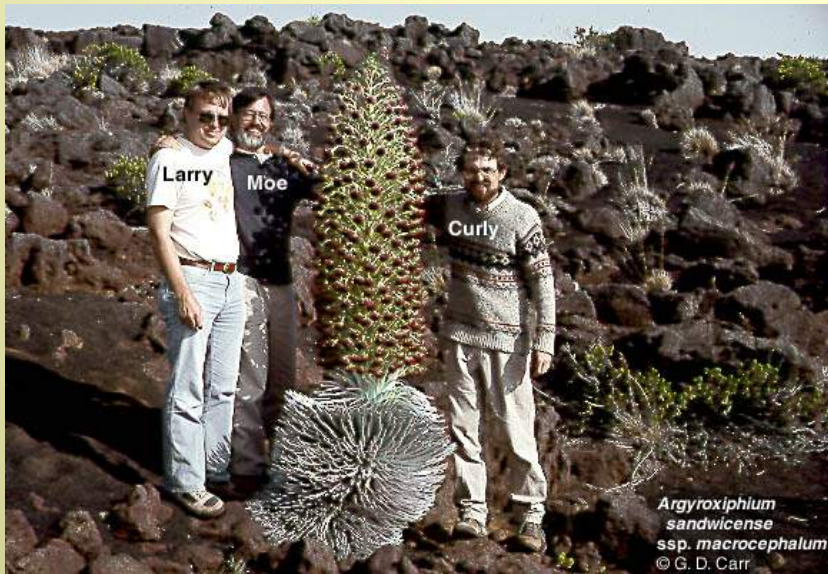


Argyroxiphium

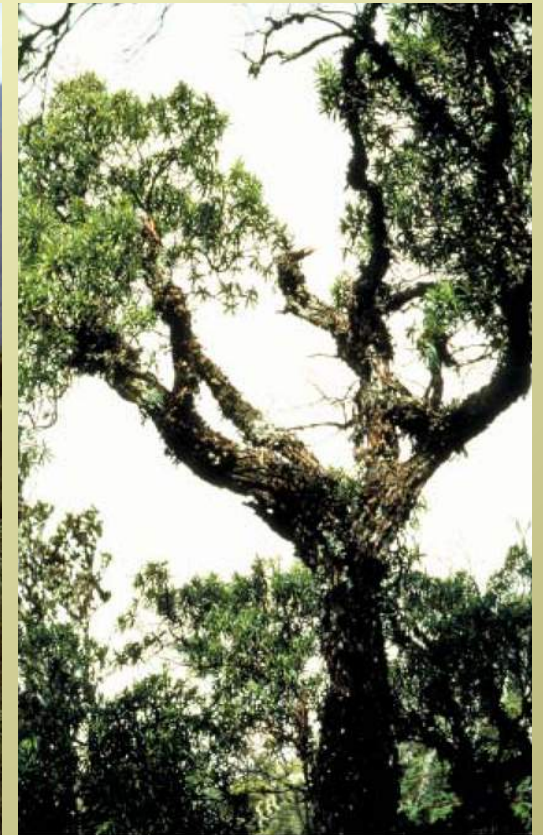
- 18-22% from western North America

Flora of Hawaii

- adaptive radiation of Hawaiian silverswords



- silversword alliance of 3 genera and 28 species
- trees, shrubs, subshrubs, rosette plants, cushion plants, vines



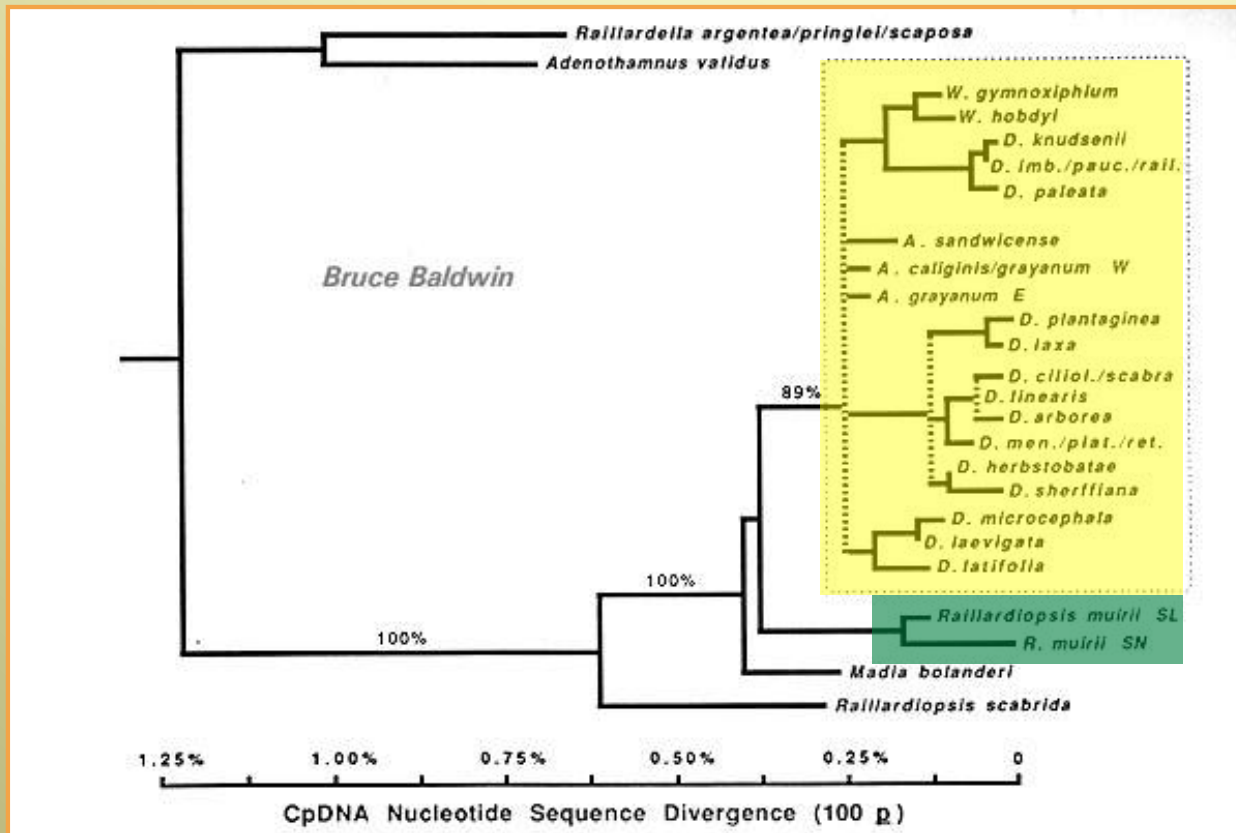
Flora of Hawaii

- adaptive radiation of Hawaiian silverswords

- B. Baldwin verified that the Hawaiian silversword radiation derived from California



Carlquistia muirii
Bruce Baldwin



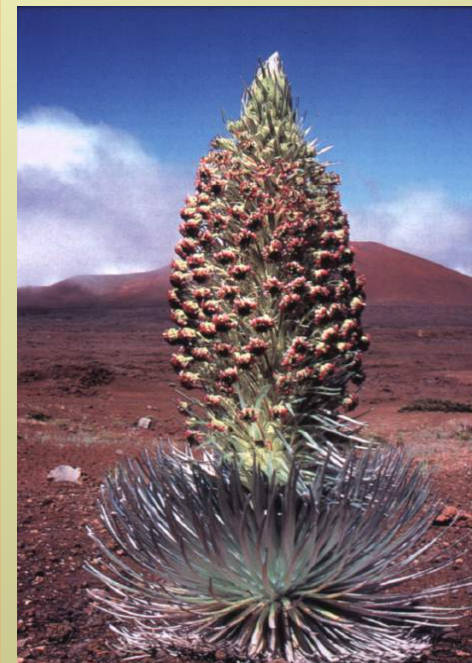
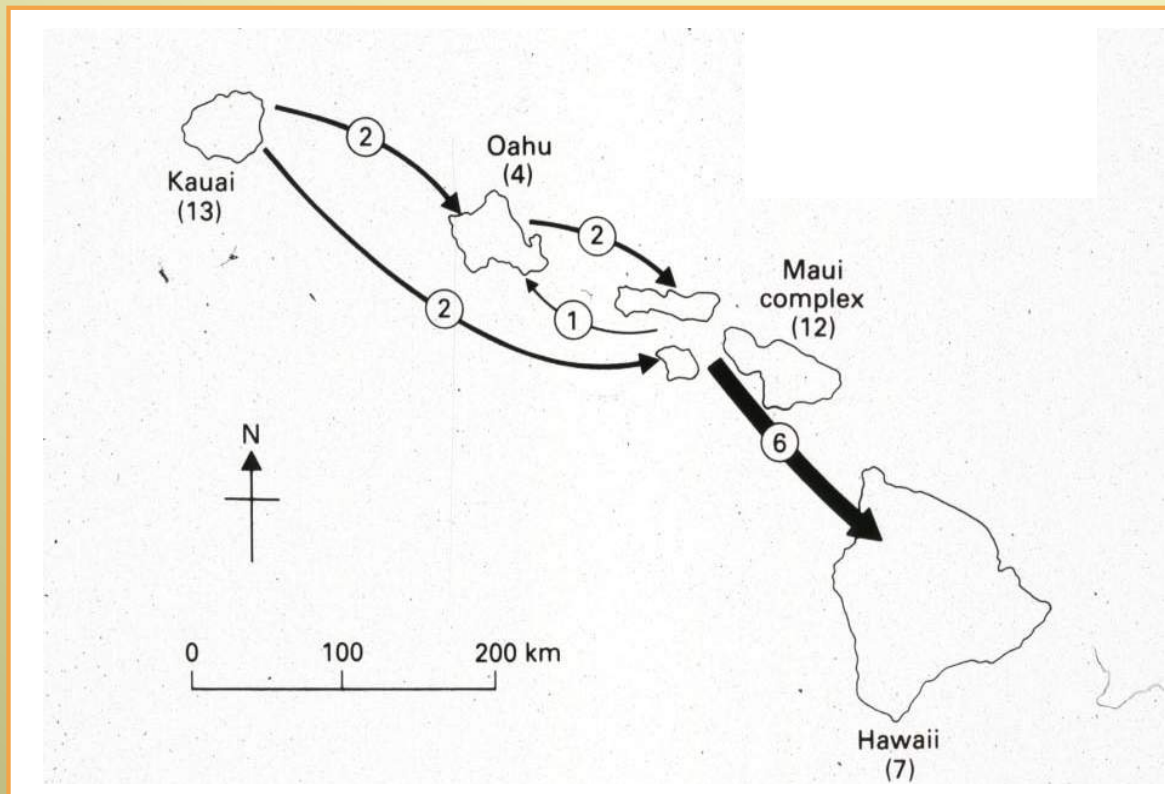
- the closest species is now called *Carlquistia muirii*
- this origin occurred about 5 mya
- rapid radiation at base

Flora of Hawaii

- **inter-island biogeography** [“island hopping” – “stepping stones”]
 - most speciation events occur on individual islands
 - few successful inter-island colonizations
 - movement is from older to younger islands



Rosemary Gillepsie



Argyroxiphium

Flora of Hawaii

- **extinction**: on-going process on islands (as well as immigration)
- but due to humans . . .
 - 107 of 956 angiosperm species — 11% extinct
 - 423 of 956 species — 38% extinct or threatened



Flora of Hawaii

- **extinction**: rogue gallery of exotics

Passiflora mollissima - banana poka

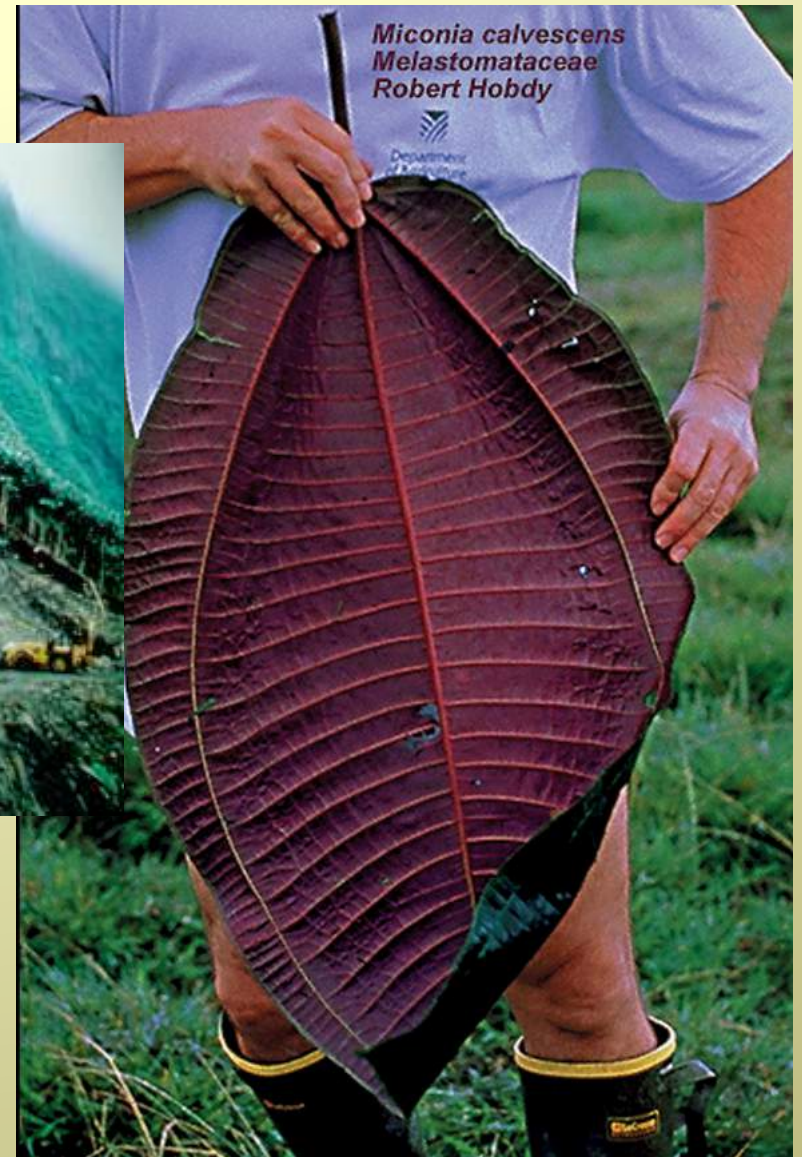


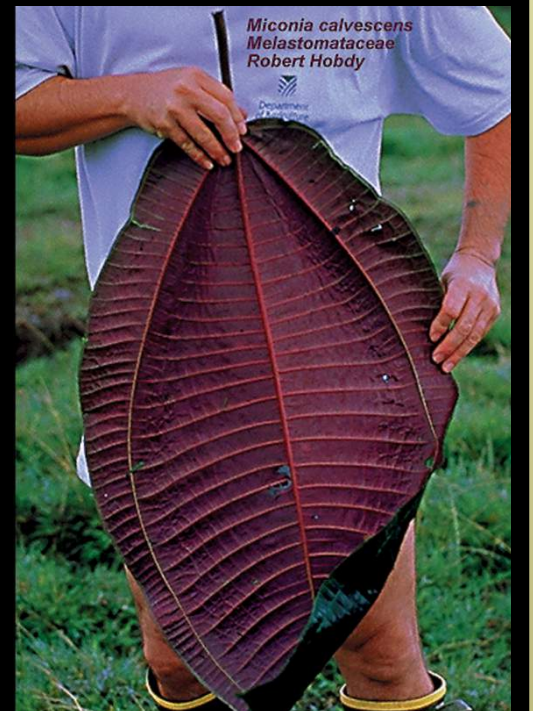
Flora of Hawaii

- **extinction**: rogue gallery of exotics

Miconia introduced into
Hawaii as ornamental

Miconia calvenscens
“green cancer”





Biogeography of Hawaii



Adaptive radiations

Hawaiian lobeliads

Hawaiian Lobeliads

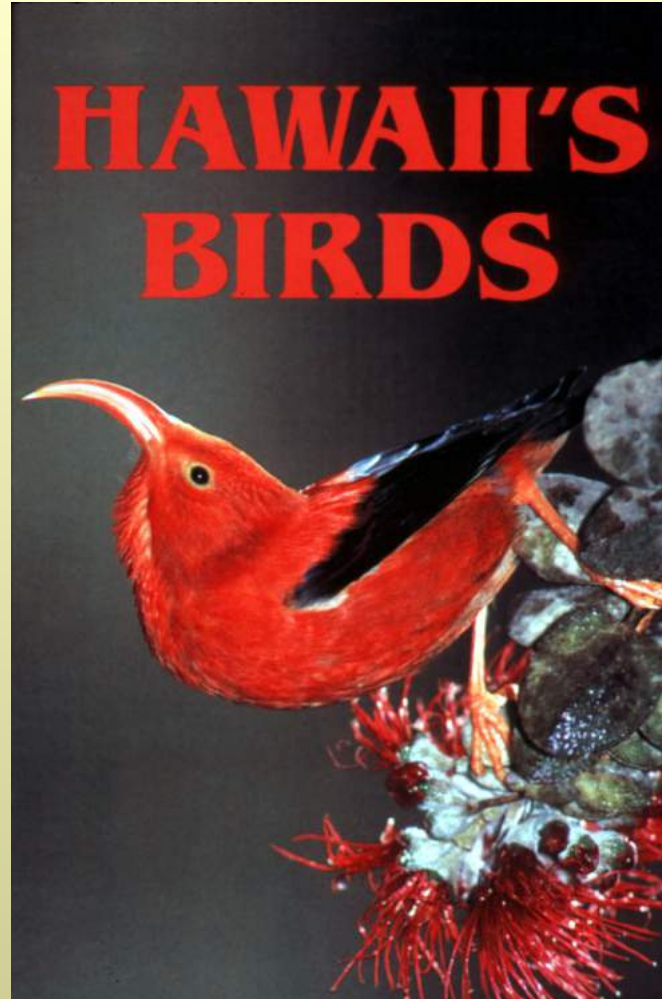
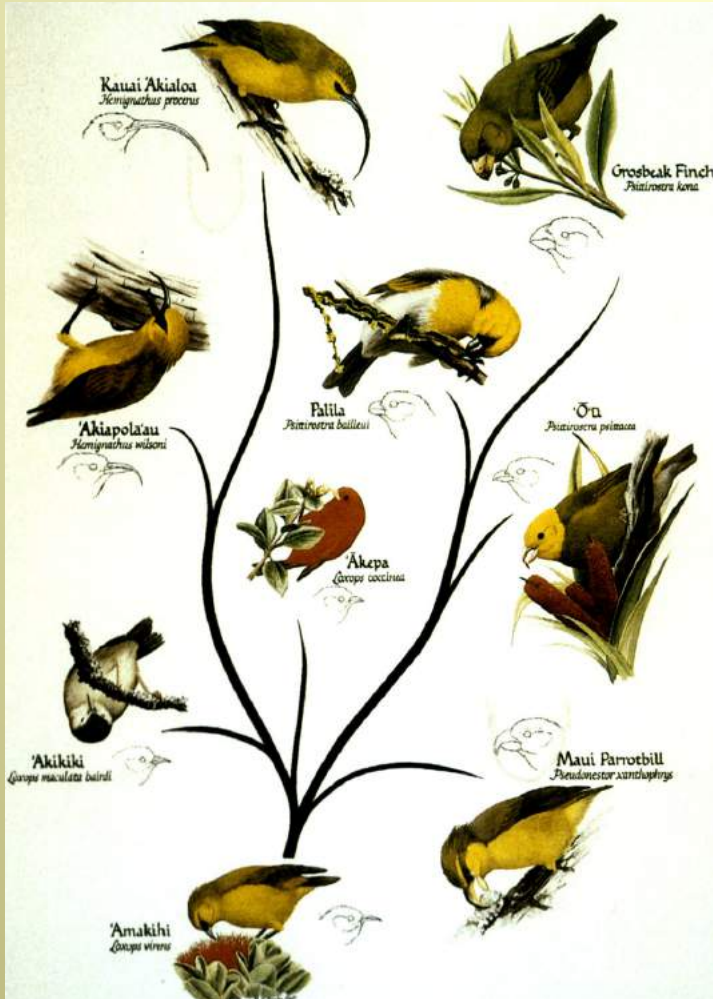
Why the **Hawaiian lobeliads**?



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

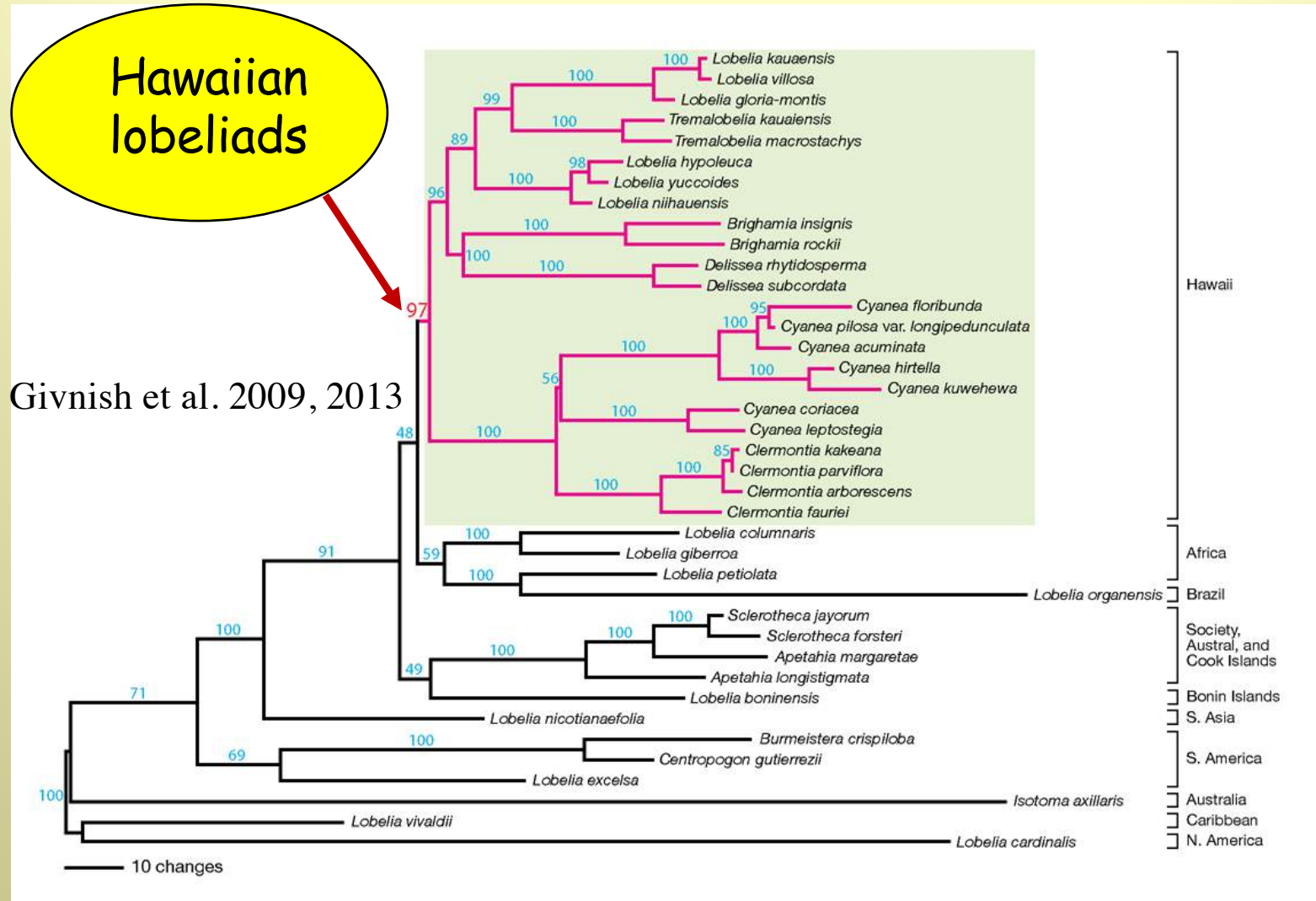
Hawaiian Lobiads

Why the **Hawaiian lobiads**?



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

Hawaiian Lobeliads

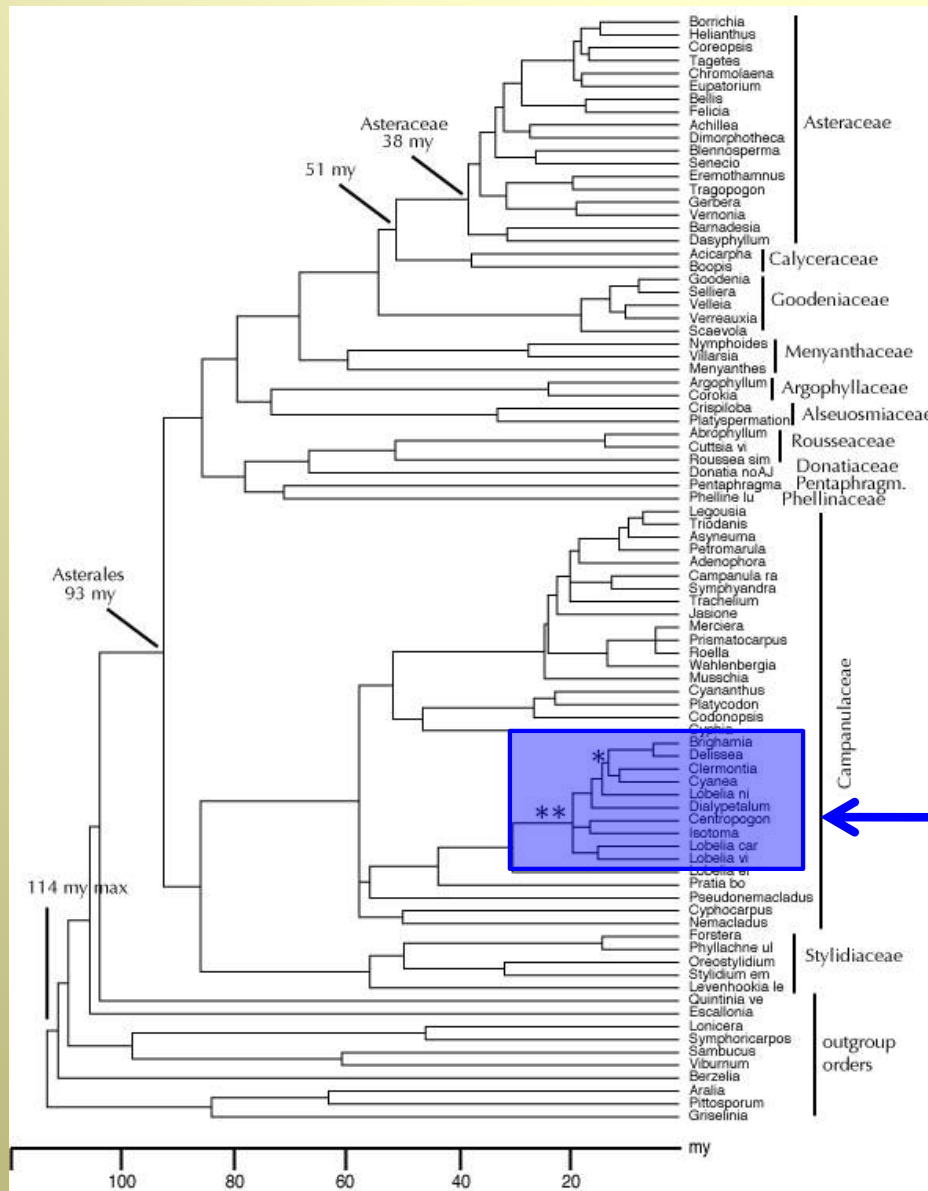


DNA supports common ancestry of ALL Hawaiian lobeliads – one single ancestral seed dispersed to Hawaii & radiated into the more than 140 species

Hawaiian Lobeliads

Two approaches for dating and placing the Hawaiian colonization

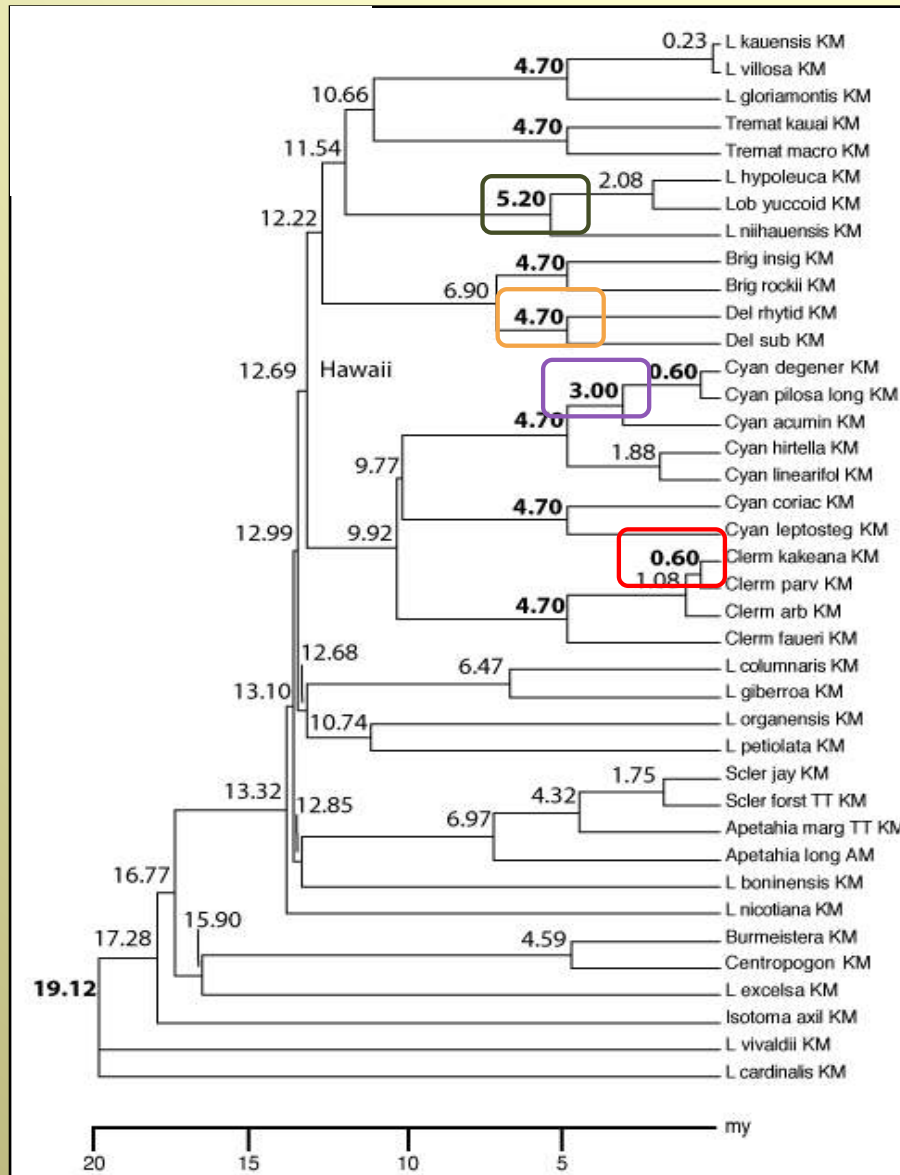
1. Calibration using an external phylogeny of the order Asterales and 5 well characterized fossils outside the family outside the family



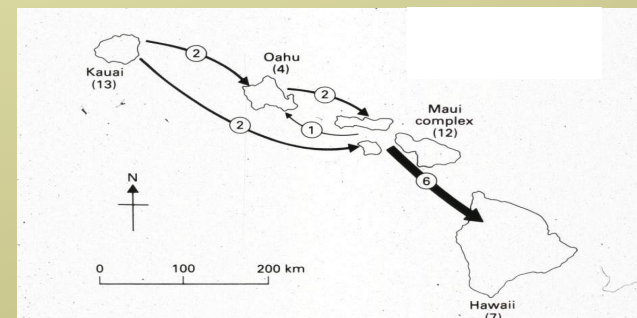
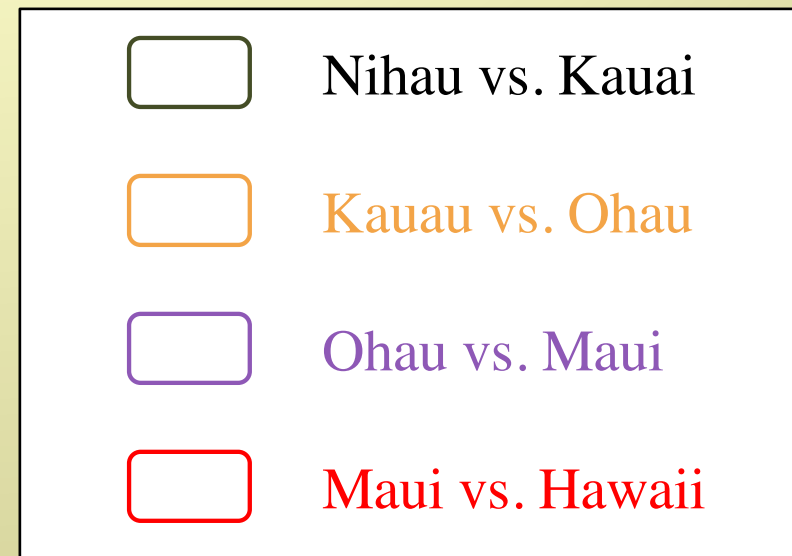
Hawaiian lobelioids

Hawaiian Lobeliads

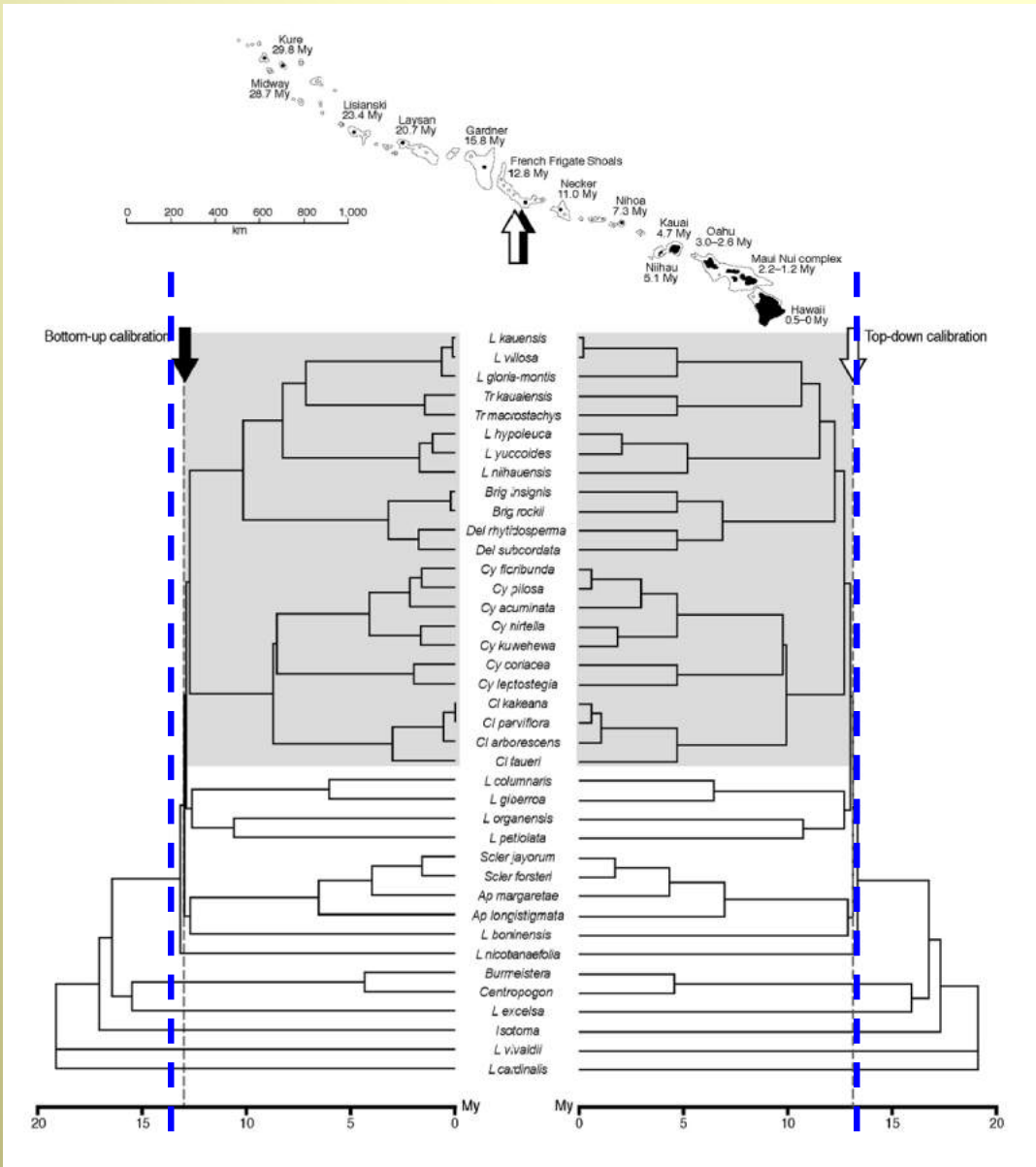
Two approaches for dating and placing the Hawaiian colonization



2. Calibration using island shifts / island ages

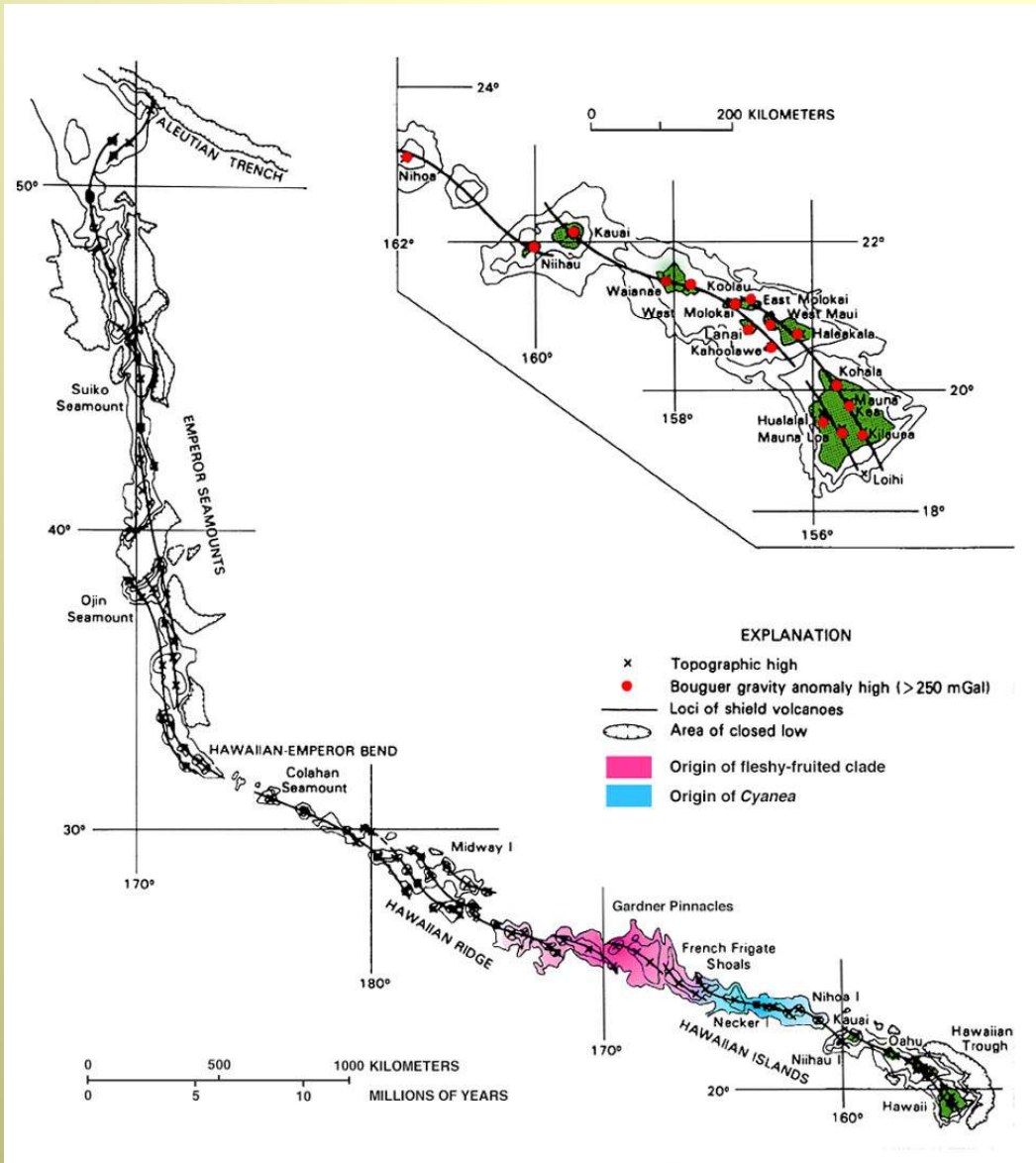


Hawaiian Lobeliads



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

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 LaPerouse/Gardner Pinnacles - large volcanic islands 10-15 mya

Hawaiian Lobeliads

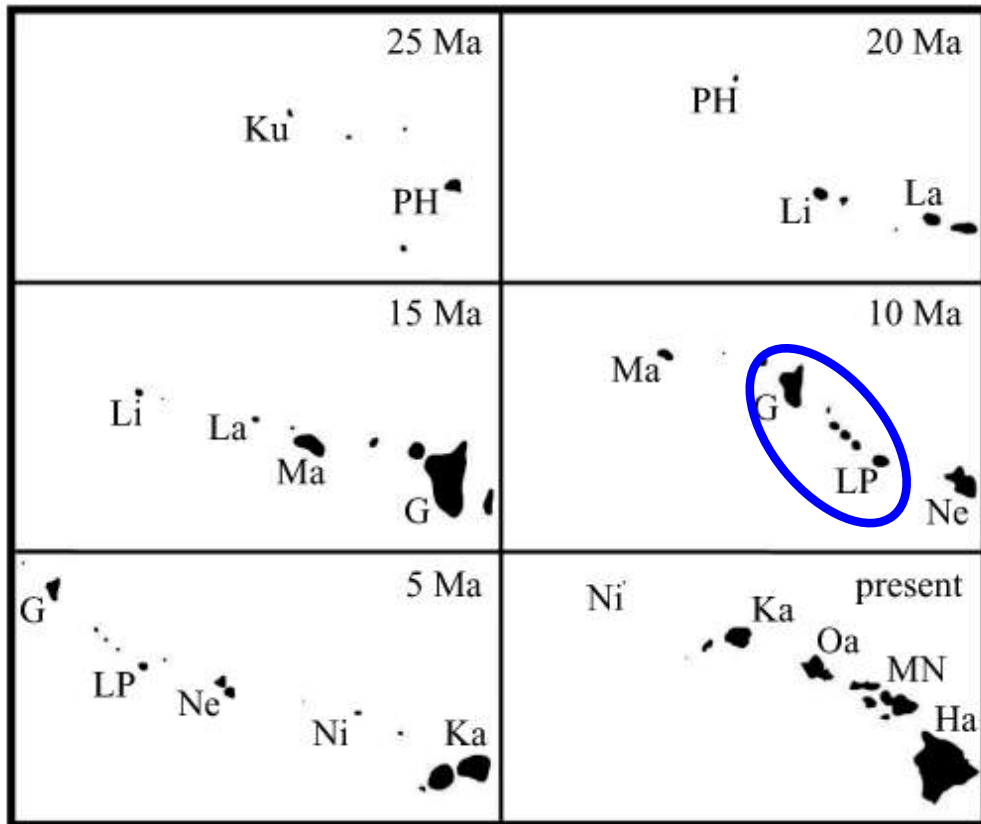
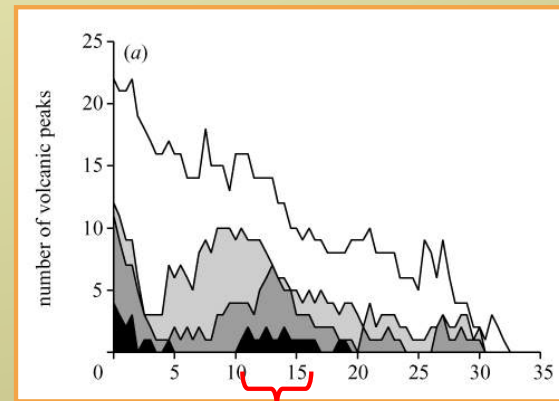


Figure 3. Island configurations at 5 Myr intervals. We adjusted a rough digital elevation model of the estimated pre-erosion surface according to height estimates for different points in time. Ku, Kure; PH, Pearl and Hermes; Li, Lisianski; La, Laysan; Ma, Maro; G, Gardner; LP, LaPerouse; Ne, Necker; Ni, Nihoa; Ka, Kauai; Oa, Oahu; MN, Maui Nui; Ha, Hawaii.

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 LaPerouse/Gardner Pinnacles - large volcanic islands 10-15 mya



Hawaiian Lobeliads

One of the oldest radiations of extant Hawaiian biota - honeycreeper pollinators would not arrive for another 7-9 my

How old is the Hawaiian biota? J. P. Price and D. A. Clague 2433

Table 1. Age estimates for MRCAs of lineages of Hawaiian organisms.^a

lineage	type of organism	no. of species	age (Ma)	method	source
Hawaiian fruitflies (Drosophilidae)	insect	ca. 1000	26	IC	Russo <i>et al.</i> (1995)
Hawaiian lobelioids (Campanulaceae)	plant	125	15	IC	Givnish <i>et al.</i> (1996)
<i>Megalagrion</i> damselflies (Coenagrionidae)	insect	23	9.6	IC	Jordan <i>et al.</i> (2003)
Silversword Alliance (Asteraceae)	plant	28	5.1	IC	Baldwin & Sanderson (1998)
Laysan duck, <i>Anas laysanensis</i> (Anatidae)	bird	1	< 5	EC	Fleischer & McIntosh (2001)
Hawaiian crows, <i>Corvus hawaiiensis</i> + other spp.? (Corvidae)	bird	1+?	< 4.2	EC	Fleischer & McIntosh (2001)
Hawaiian honeycreepers, Drepanidinae (Fringillidae)	bird	ca. 50	4-5	IC	Fleischer <i>et al.</i> (1998)
<i>Viola</i> spp. (Violaceae)	plant	6	3.7	BS, LD	Ballard & Sytsma (2000)
flightless Anseriformes, 'moa-nalos' (Anatidae)	bird	4	< 3.6	EC	Sorenson <i>et al.</i> (1999)
Hawaiian thrushes, <i>Myadestes</i> spp. (Muscicapidae)	bird	5	< 3.35	EC	Fleischer & McIntosh (2001)
<i>Kokia</i> spp. (Malvaceae)	plant	4	< 3	EC	Seelanan <i>et al.</i> (1997)
flightless rails, <i>Porzana sandwicensis</i> + other spp.? (Rallidae)	bird	1+?	< 2.95	EC	Fleischer & McIntosh (2001)
<i>Geranium</i> spp. (Geraniaceae)	plant	6	2	BS	Funk & Wagner (1995)
<i>Hesperomannia</i> spp. (Asteraceae)	plant	4	1.81-4.91	EC	Kim <i>et al.</i> (1998)
flightless ibises, <i>Apteribis</i> spp. (Plataleidae)	bird	2	< 1.6	EC	Fleischer & McIntosh (2001)
Hawaiian duck, <i>Anas wyvilliana</i> (Anatidae)	bird	1	< 1.5	EC	Fleischer & McIntosh (2001)
flightless rails, <i>Porzana palmeri</i> + other spp.? (Rallidae)	bird	1+?	< 1.05	EC	Fleischer & McIntosh (2001)
Hawaiian geese, <i>Branta</i> spp. (Anatidae)	bird	3	< 1	EC, LD	Fleischer & McIntosh (2001)
Hawaiian black-necked stilt, <i>Himantopus mexicanus knudsenii</i> (Recurvirostridae)	bird	1	< 0.75	EC	Fleischer & McIntosh (2001)
Hawaiian hawk, <i>Buteo solitarius</i> (Accipitridae)	bird	1	< 0.7	EC	Fleischer & McIntosh (2001)
<i>Tetramolopium</i> spp. (Asteraceae)	plant	11	0.6-0.7	EC, LD	Lowrey (1995)
<i>Metrosideros</i> spp. (Myrtaceae)	plant	5	0.5-1.0	LD	Wright <i>et al.</i> (2001)



Hawaiian Lobeliads

But . . . a 2008 paper shows that the 5 recently extinct **Hawaiian Honeyeaters** – thought to be recently derived from **AustralAsian Honeyeaters** – are in fact 14-17 my old and derived from an American clade - waxwings, silky flycatchers, and palm chats

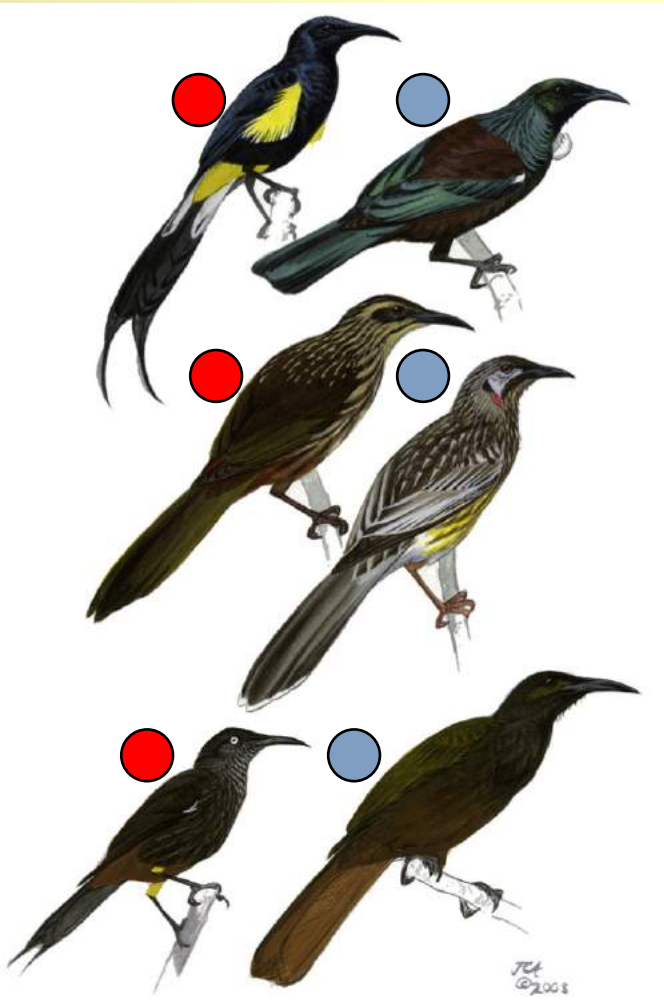


Figure 2. Illustrations of Three of the Five Species of Hawaiian "Honeyeater" and Three Representative Meliphagid Honeyeaters

The three Hawaiian taxa represent the three primary morphological types found in Hawaiian "honeyeaters" (Mohoidae: [A], *Moho nobilis*; [C], *Chaetoptila angustipluma*; and [E], *Moho braccatus*). The three meliphagids include one from New Zealand ([B], *Prothemadera novaeseelandiae*), one from Australia ([D], *Anthochaera carunculata*), and one from Samoa ([F], *Gymnomyza samoensis*). Paintings are by John Anderton and are used here with permission.

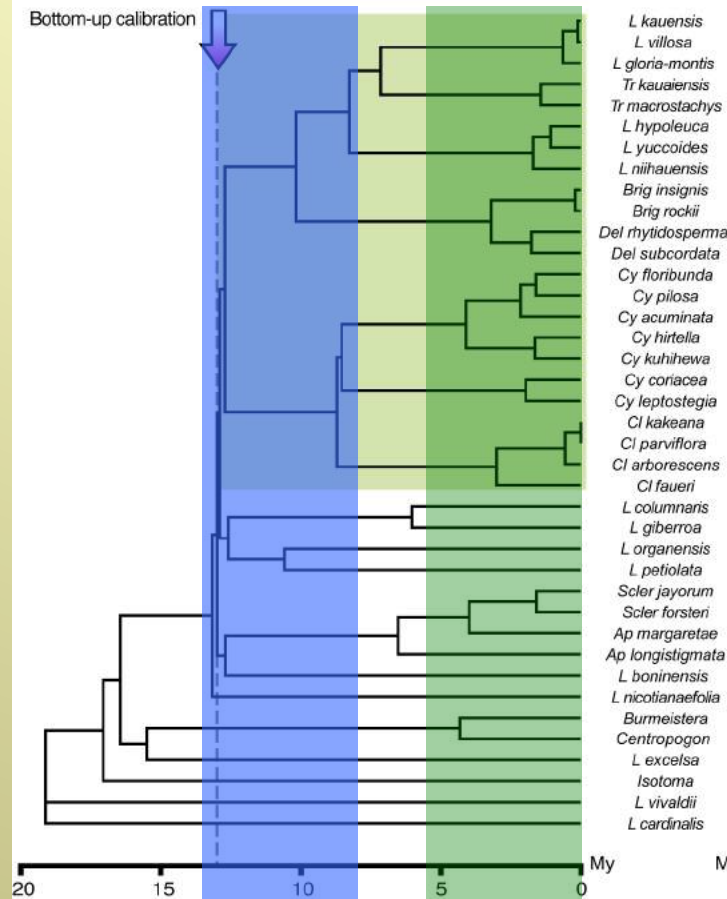
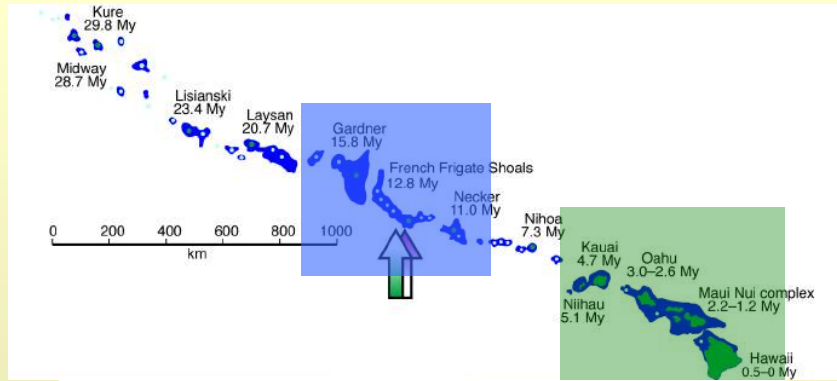
Hawaiian
lobeliads 13-14
mya



Hawaiian
Honeycreepers 7 mya



Hawaiian Lobeliads



• Early lobeliads had initial radiation with Hawaiian honeyeaters

• later radiation of two large genera (*Cyanea* and *Clermontia*) primarily with Hawaiian honeycreepers

An aerial photograph of a volcanic island chain. The foreground features a large, dark, conical volcano with a visible crater. The surrounding water is a vibrant blue, showing varying depths and textures. In the distance, several smaller, rocky islands are visible against a clear blue sky.

*“Assume nothing in Hawaiian
natural history”*