DICE
UNIVERSITY OF KENT

Durrell Institute for Conservation & Ecology

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ISLA 2007 - Mauritius

Summary

1. Physical processes important for islands
2. Speciation on islands

   case-studies from Galapagos, Hawaii, Mauritius

3. Common features of island species
4. <u>Question:</u> Is extinction a feature of island species?

What determines an islands biota?

Physical features:

elevation
area
geology
location
isolation
origin
climate

What determines an islands biota?

<u>Climatic trends:</u>
Tall islands=wetter   Low islands=drier

<u>Habitat compression</u>
Altitudinal zones become *compressed* on islands.

This increases the number of species that an island can support.

Maldives

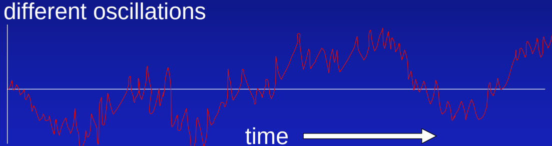
Galapagos

Hawaii

What determines an islands biota?

<u>Climatic trends:</u>
Climatic variation - short-term variation has a lower wave-length than longer-term variation.

On an evolutionary timescale, populations experience different oscillations



Climate can limit successful colonization of an island

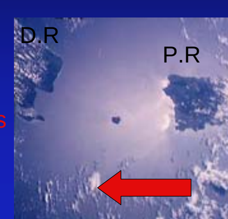
What determines an islands biota?

<u>Climatic trends:</u>
Ocean & wind currents can have large influence.

Mona Island, Caribbean: constant east-to-west winds.

9 endemic butterfly subspecies on Mona Island.

All originate from Puerto Rico



What determines an islands biota?

Climatic trends:
Natural disturbance re-distributes resources for new species.

Island systems are largely structured by disturbance (volcanism, tsunamis, hurricanes)

Magnitude & frequency (i.e El Nino events, cyclones)

Models of evolution on islands

Anagenesis

- speciation with little or no radiation
- uncommon (or not frequently studied?)
- occurs on the smallest, most isolated islands

Eg. Juan Fernandez Islands, 600 km off Chilean coast. 67% plant species are endemic.

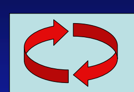
73 'colonisation events' can explain 69 (71%) of the endemic genera.

Models of evolution on islands

Taxon Cycles

A succession of colonisation.

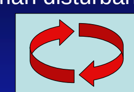
1. Initial invasion by colonist (Spp 1)
2. Expansion to other habitats
3. Colonises as generalist
4. Evolves locally restricted forms
5. New colonist arrives (Spp 2)
6. Out-competes the first colonist (Spp 1 now specialist)
7. Spp 1 and Spp 2 become highly differentiated
8. Specialist becomes extinct (changes in environment)
9. Empty niches filled by new colonists (Spp 3)



Models of evolution on islands

Taxon Cycles

Difficult to observe due to historical human disturbance



Important concept:
Species move from marginal to interior habitats.

Do island communities really evolve like this?

Mauritian skinks?

Models of evolution on islands

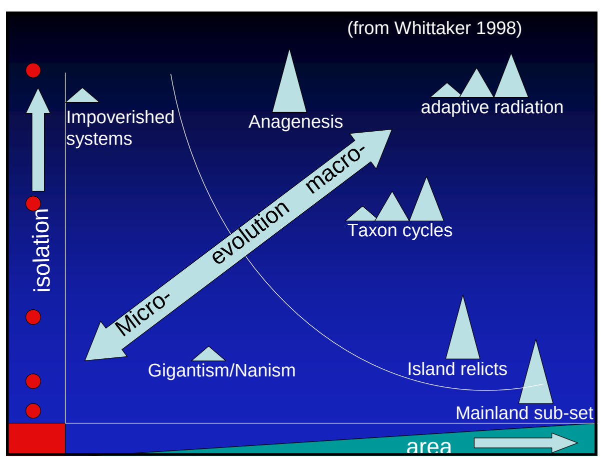
Adaptive radiation

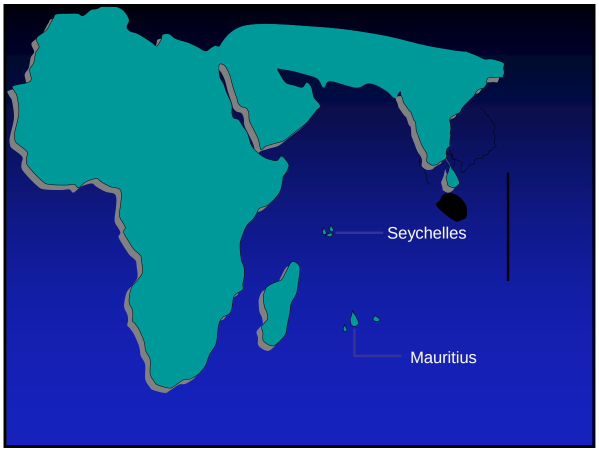
Diversification of species into vacant niche space.

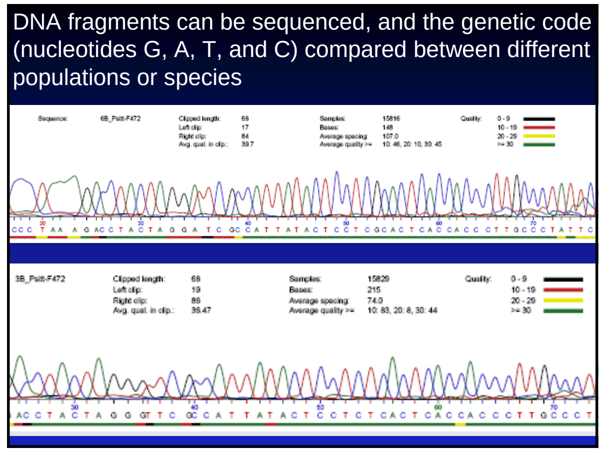
Most well known model.

Hawaiian insects:
10,000 species from ~ 350 colonist species

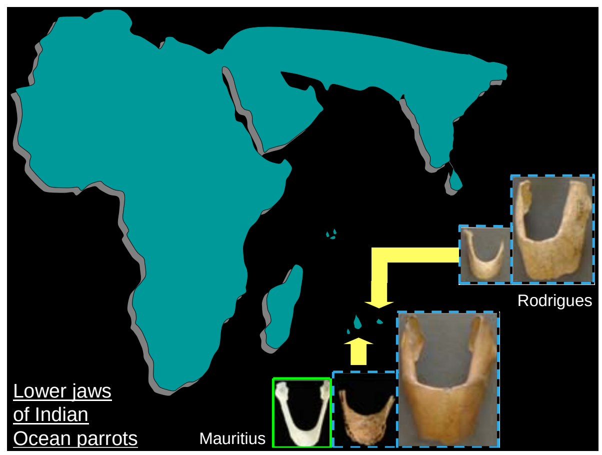
Most common on remote, high, islands on edge of a biotic groups dispersal range

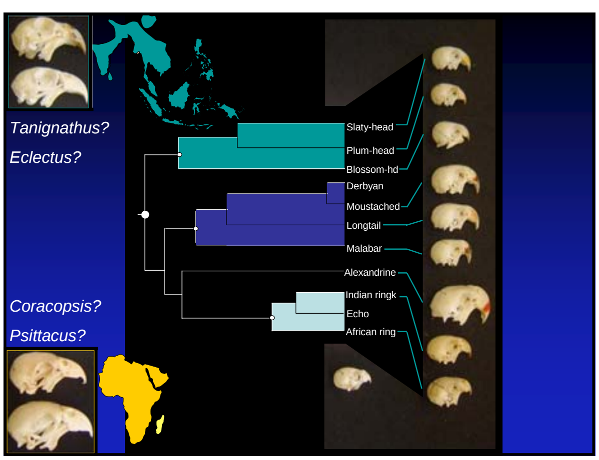


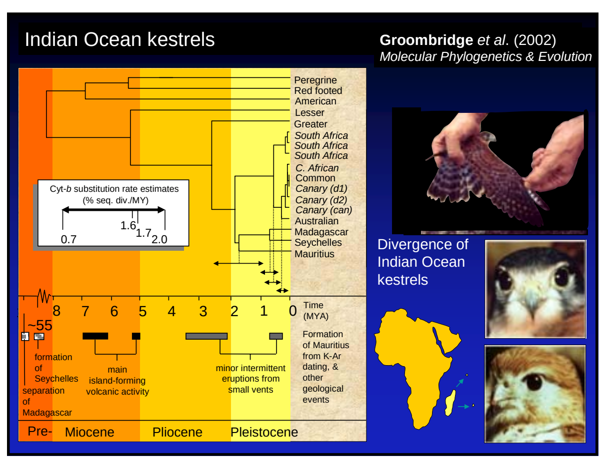

Seychelles
Mauritius

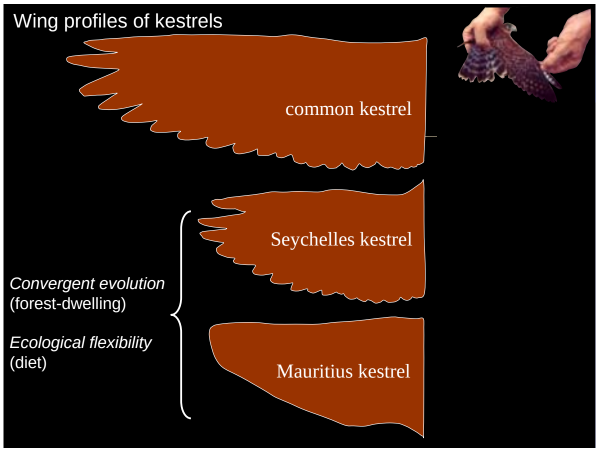

DNA fragments can be sequenced, and the genetic code (nucleotides G, A, T, and C) compared between different populations or species


Evolution of the Mauritius parakeet


Rodrigues
Lower jaws
of Indian
Ocean parrots
Mauritius


Tanignathus?
Eclectus?
Coracopsis?
Psittacus?
Slaty-head
Plum-head
Blossom-hd
Derbyan
Moustached
Longtail
Malabar
Alexandrine
Indian ringk
Echo
African ring


Indian Ocean kestrels
Groombridge et al. (2002)
Molecular Phylogenetics & Evolution
Peregrine
Red footed
American
Lesser
Greater
South Africa
South Africa
South Africa
C. African
Common
Canary (d1)
Canary (d2)
Canary (can)
Australian
Madagascar
Seychelles
Mauritius
Cyt-b substitution rate estimates
(% seq. div./MY)
0.7
1.6
1.7
2.0
~55
8 7 6 5 4 3 2 1 0
Time (MYA)
formation of Seychelles
separation of Madagascar
main island-forming volcanic activity
minor intermittent eruptions from small vents
Formation of Mauritius from K-Ar dating, & other geological events
Pre-
Miocene
Pliocene
Pleistocene
Divergence of Indian Ocean kestrels



Island models of evolutionary change

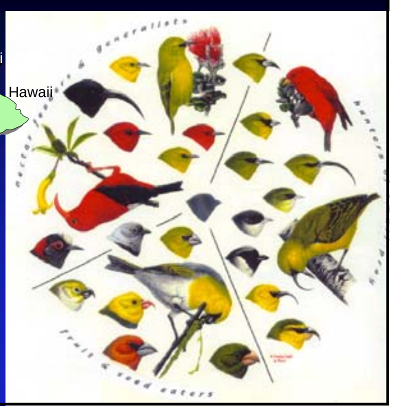
Adaptive radiation
Eg. Hawaiian honeycreepers

1 x ancestral seeding-eating finch

- seed-eaters
- insectivors
- nectivors
- frugivors

One ancestral seeding-eating finch radiated into 33 species in 11 genera (fossils hold 14 more species)

Adaptive radiation: Eg. Hawaiian honeycreepers



Radiation in:

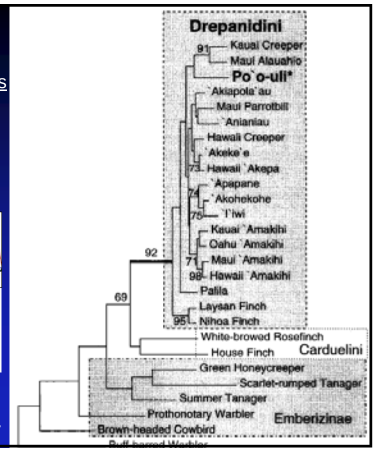
Bill morphology

Feeding ecology

Plumage

Molecular phylogeny of Hawaiian honeycreepers

mtDNA *cytochrome-b* evolves relatively slowly



Adaptive radiation: Eg. Hawaiian honeycreepers

'Iiwi
(*Vestiaria coccinea*)
-nectivor specialist.
-Common.
-Feeds on 'Ohia blooms on top of forest canopy.

-Migrates up and down slope to follow flower blooming cycles.

-Common across all islands.

Adaptive radiation: Eg. Hawaiian honeycreepers

Maui Parrotbill
Pseudonestor xanthophrys
-Critically Endangered
-Insectivor specialist.
-Feeds on insect larvae.
-Excavates dead wood.
-Uses powerful beak.
-Breaks down dead branches.

Adaptive radiation: Eg. Hawaiian honeycreepers

‘Akiapola’au
(*Hemignathus munroi*)

-Critically Endangered

-Excavator specialist

-Specially adapted lower mandible that can ‘articulate’

Adaptive radiation: Eg. Hawaiian honeycreepers

Po’o-uli
(*Melamprosops phaeosoma*)

-Critically Endangered
-(Extinct???)
-(n = 2)

-excavator specialist

-feeds on snails

Adaptive radiation: Eg. Hawaiian honeycreepers

‘Akialoa
(*Hemignathus spps.*)

-Nectivor specialist
-Different subspecies on different islands.

-All species are now extinct

Adaptive radiation: Eg. Hawaiian honeycreepers

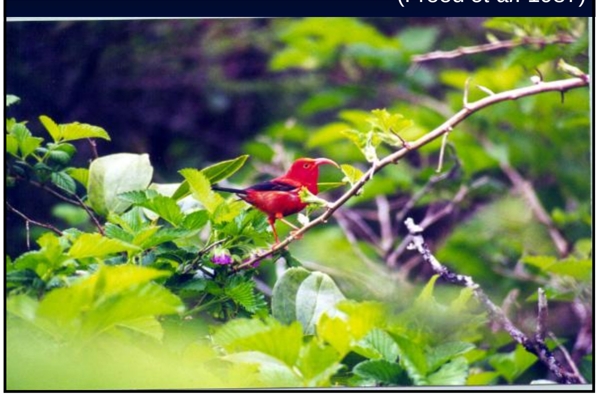
Hawaiian honeycreepers are genetically less divergent than suggested by their spectacular morphology.

A relatively recent colonisation event.
(most species are younger than ~5 MYA)

Fleischer *et al.* (1998) Evolution on a volcanic conveyor-belt… *Molecular Ecology* 7: 533-545.

Recent extinctions have allowed ecologically similar species to recolonise empty ‘ecological niches’ (‘O’o and ‘Iiwi)

Upper beak length in ‘Iiwi has shortened since 1860 (Freed *et al*. 1987)



Adaptive radiation in plants

Eg. Hawaiian lobelioids - explosive adaptive radiation in plants.

Colonised Hawaiian islands 8-17 million years ago.

105 species. Pollinated by honeycreepers.

Some plant traits have evolved SINCE the origin of their honeycreeper pollinators.

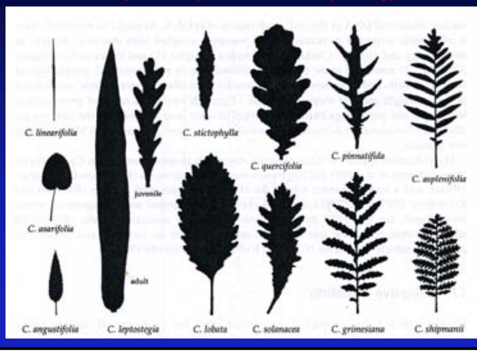
A full range of flower tubule lengths has evolved on EACH Hawaiian island

Lobelia gloriamontis

Adaptive radiation in plants

Eg. Hawaiian lobelioids

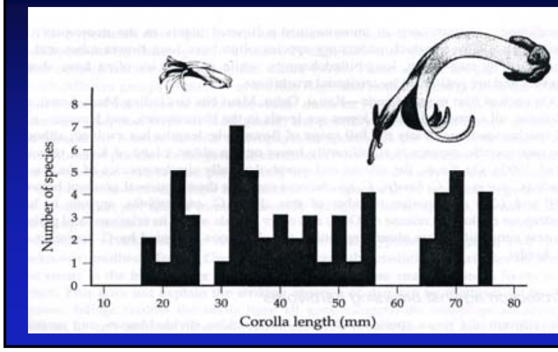
Variation in *Cyanea* species leaf morphology



Adaptive radiation in plants

Hawaiian lobelioids

Corrolla length varies across *Cyanea* species



Adaptive radiation in plants

Phylogeny of Hawaiian *Lobelia*

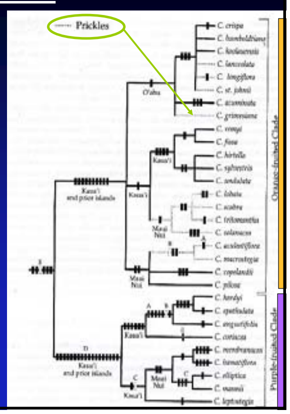
Two 'clades'
(purple-fruited & orange-fruited)

Orange-fruited spps
Wetter habitat
Conspicuous in dark forest

Purple-fruited spps
Drier habitats
Conspicuous in open habitat

Prickles evolved independently
as a defence against herbivores

Sub-fossils have been found
of giant flightless geese



Adaptive radiation in plants

Hawaiian *Lobelia* - diversity in *Cyanea* morphology

C. asarifolia *C. crispa* *C. tritomantha*

Adaptive radiation in plants

Hawaiian *Lobelia* - diversity in *Cyanea* morphology

C. pinnatifida *C. dunbarii*

C. platyphylla

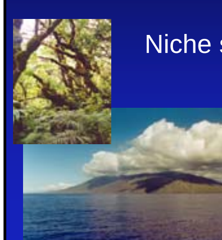
Evolutionary traits of island species

Endemicity

Niche shifts - loss of dispersability

- gigantism / nanism

- character displacement



Evolutionary traits of island species

Endemicity on islands:

Levels of endemism can be very high…

Land snails - Hawaii 99% endemic (~1000 spps.)
- New Caledonia 99% endemic

…or very low

Lizards - Hawaii only 3 species, no endemics
Mammals - Mauritius & Hawaii=1 spp each

Island species often evolve from 'good' dispersers


Succineid snails in Hawaii


Po'o-uli (n=2)
Melamprosops phaeosoma


Almost extinct

Evolutionary traits of island species

Loss of dispersability:

Hawaii flora -
Genus *Bidens*
(Spanish Needle)

Mainland species - left
Hooked

Island endemics - right
Hooks lost

(loss of non-required features)

Evolutionary traits of island species

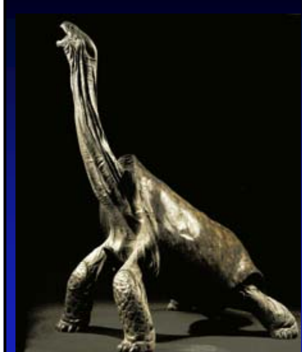
Change in size:

Changes in size can occur on islands (no predation, competition for food resources, selection)

85% of rodent species on islands are larger than mainland ancestors

Gigantism

Nanism:
Elephas falconeri on island of Malta



Evolutionary traits of island species

Change in size:

Larger or smaller?

Coloniser arrives on predator-free island

Population density increases on the island

Resources become limited

Gigantism

Selective pressure for larger body-size through dominance hierarchy (i.e. rodents, lizards)

Nanism

Selective pressure for smaller body-size as an aggression-reducing strategy (i.e. snakes & some mammals)

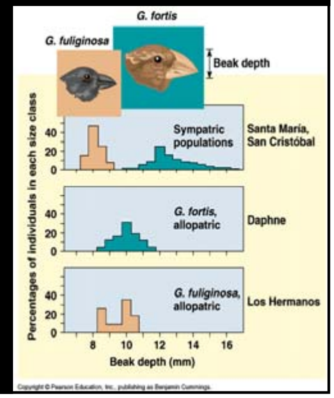
Evolutionary traits

Character displacement:

Galapagos ground finches.

Similar beak depth on different islands, but beak depth is different for each species when they occur together on the same island.

Important implications for conservation biologists



Is *extinction* an evolutionary trait of island species?

Island colonists must survive:

1. environmental fluctuations
2. catastrophes
3. small [founding] population size
   - Inbreeding depression
   - Loss of genetic variation
   - Fixation of deleterious mutations

Are island species more likely to go extinct than mainland species?

Is *extinction* an evolutionary trait of island species?

Clermontia plants in Hawaii are pollinated only by honeycreepers.

Clermontia peleana is now extinct.

Which extinct honeycreeper served as its pollinator?

Clermontia peleana

Understanding how island species have **evolved** can help save them