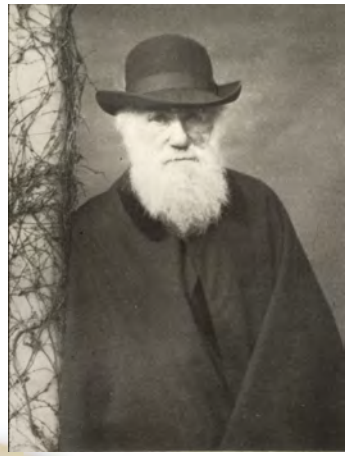
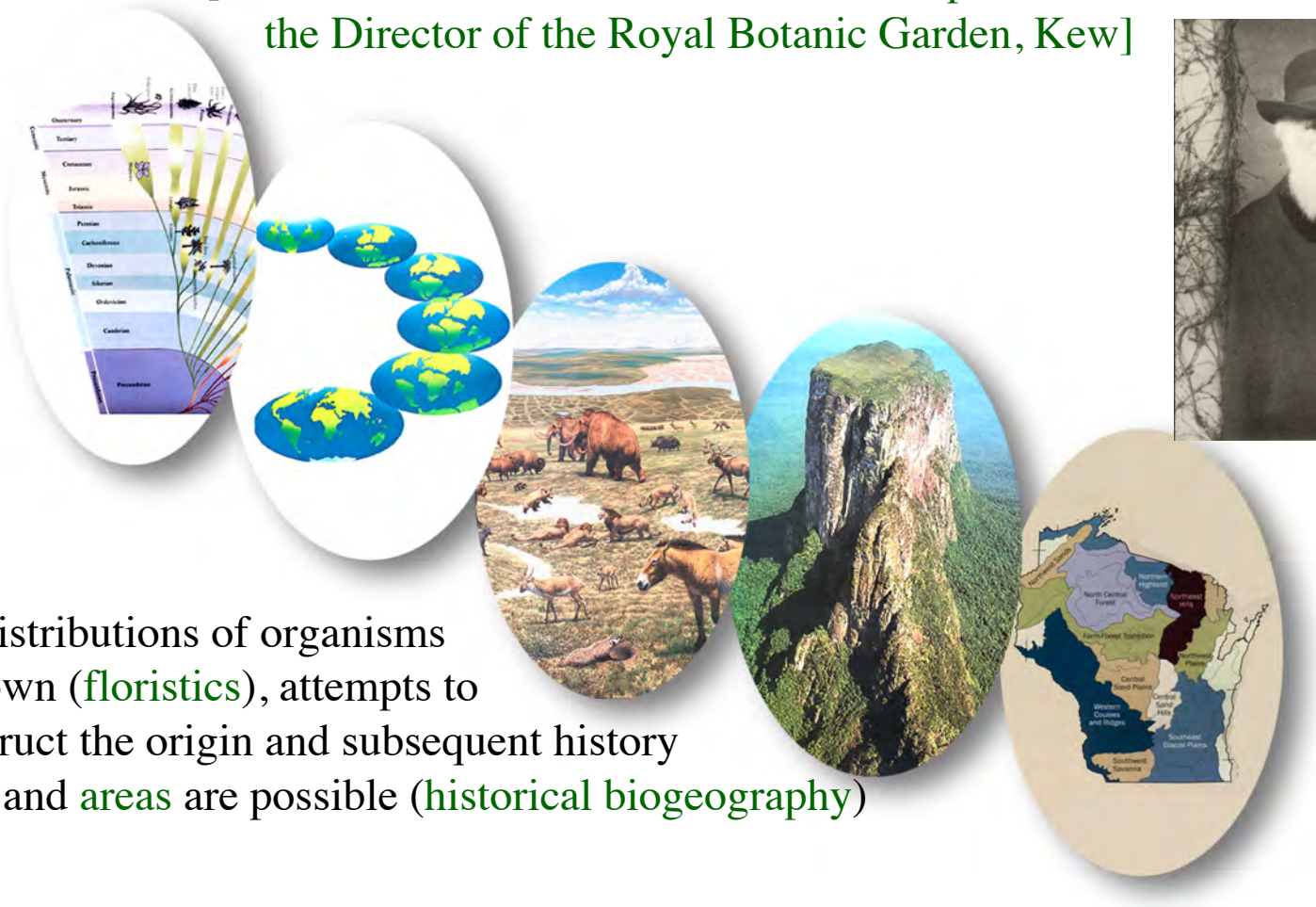
Historical Biogeography

" . . . *that grand subject, that almost keystone of the laws of creation,* ***Geographical Distribution***"

[Charles Darwin, 1845, in a letter to Joseph Dalton Hooker, the Director of the Royal Botanic Garden, Kew]





Once distributions of organisms are known (floristics), attempts to reconstruct the origin and subsequent history of taxa and areas are possible (historical biogeography)

Historical Biogeography

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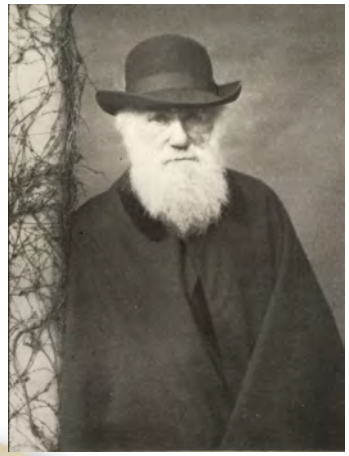
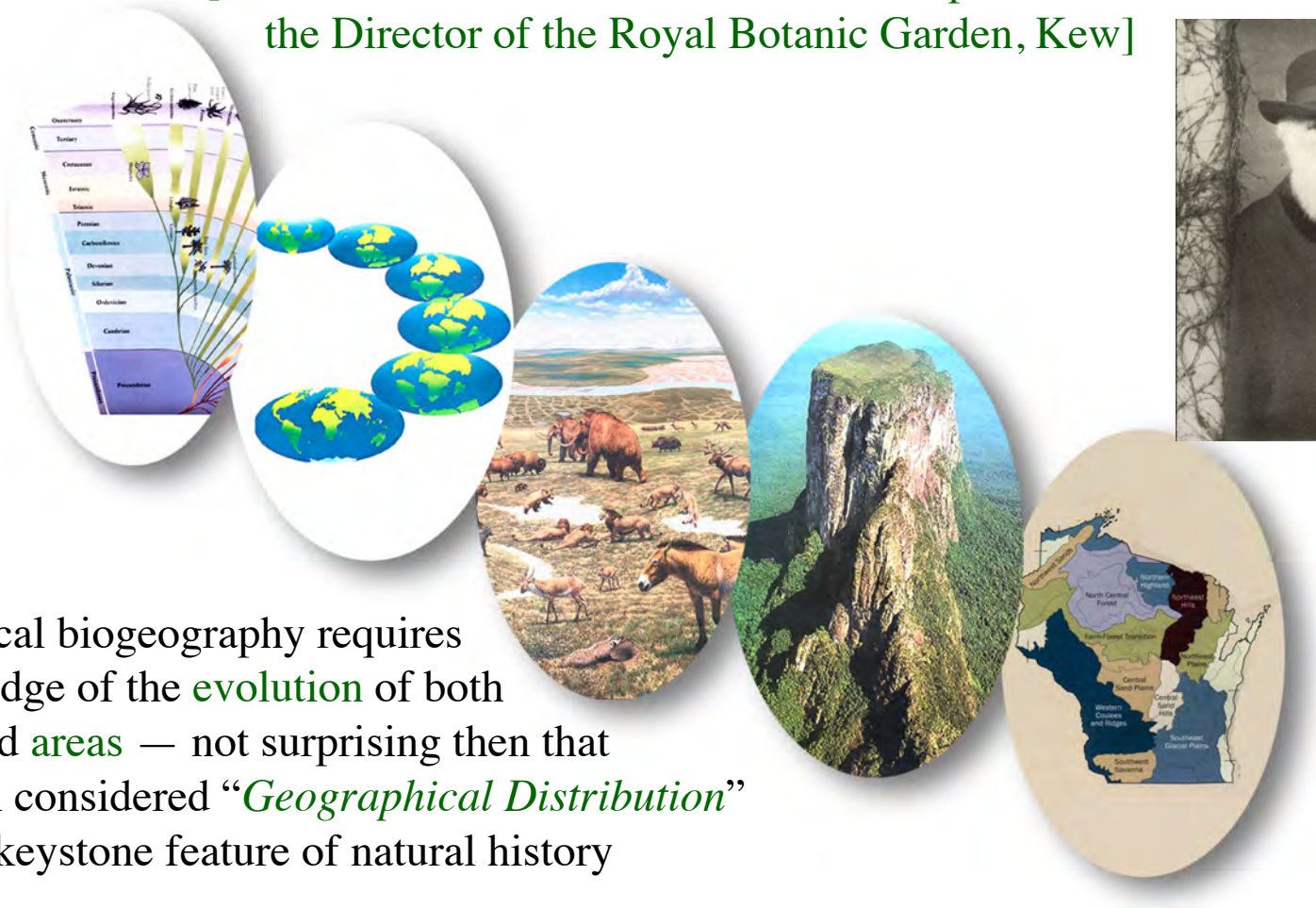
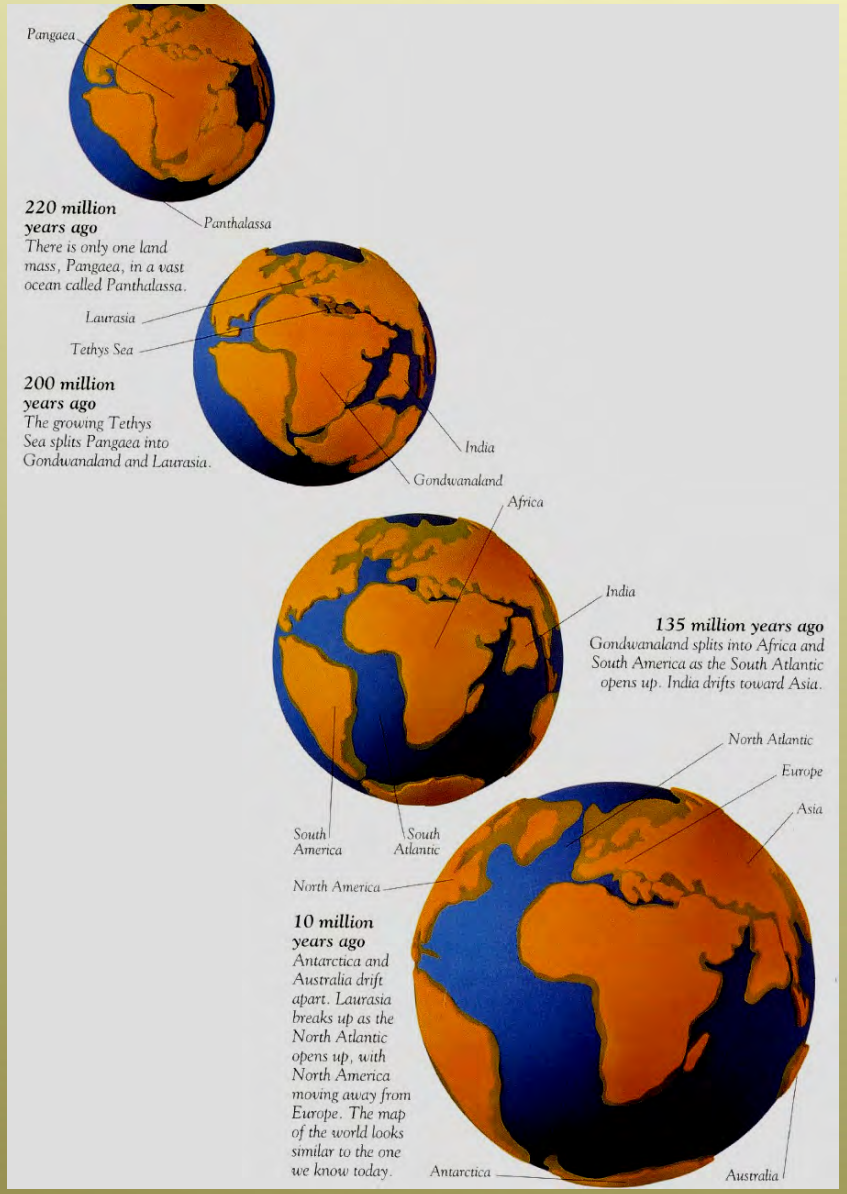




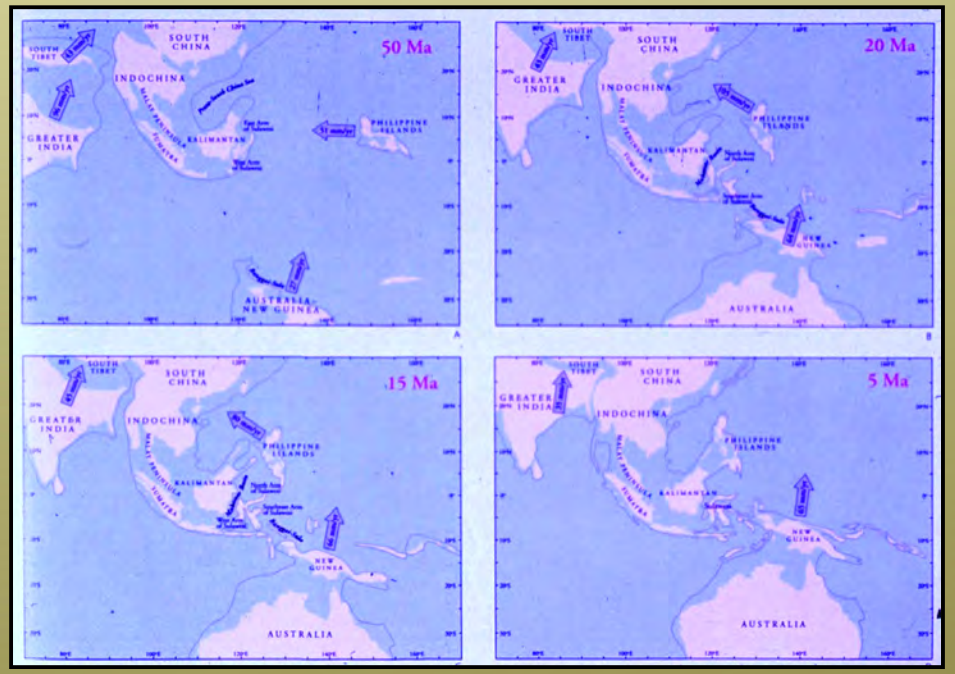
Historical biogeography requires knowledge of the evolution of both taxa and areas — not surprising then that Darwin considered "*Geographical Distribution*" such a keystone feature of natural history

Historical Biogeography

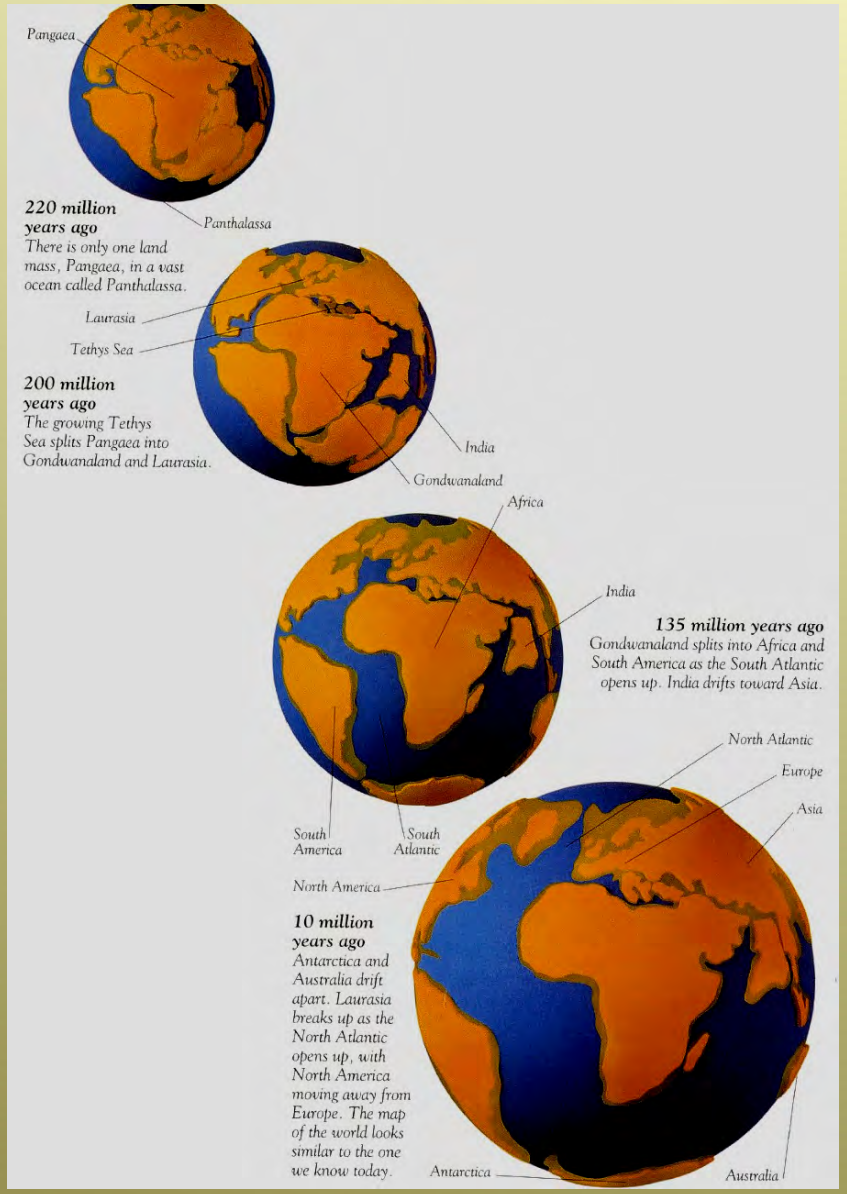


- The environmental setting (climate, wind and ocean currents, positions of landmasses, vegetation types) has not been constant or static over time — but dynamic

Plate tectonics showing major movements of Africa, India, and Australia

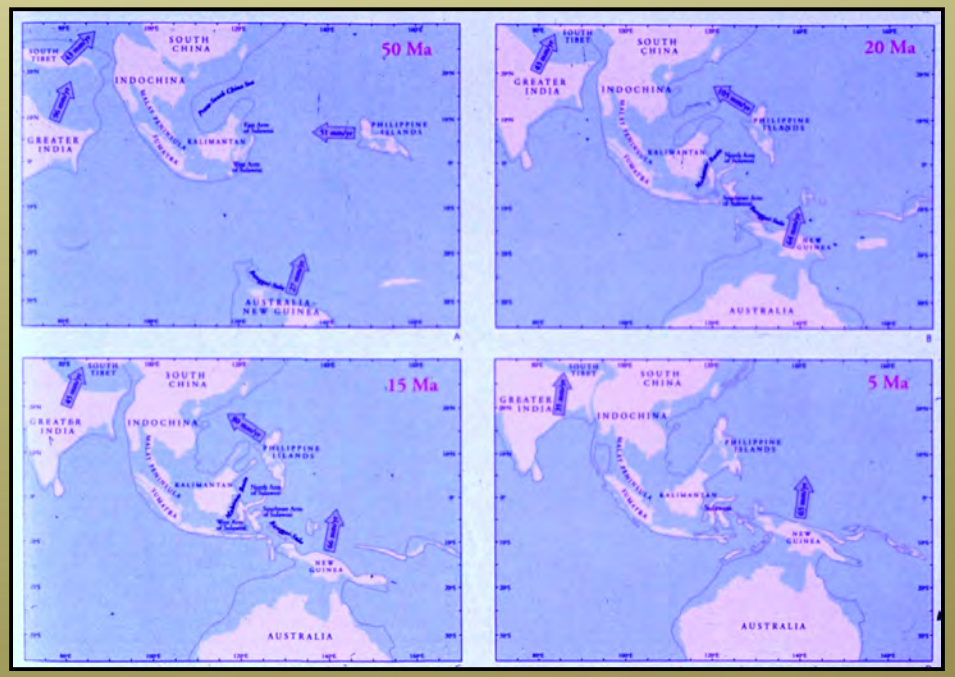


Historical Biogeography



- This geological evolution (area evolution) is thus an important component of the "historical setting" or historical biogeography

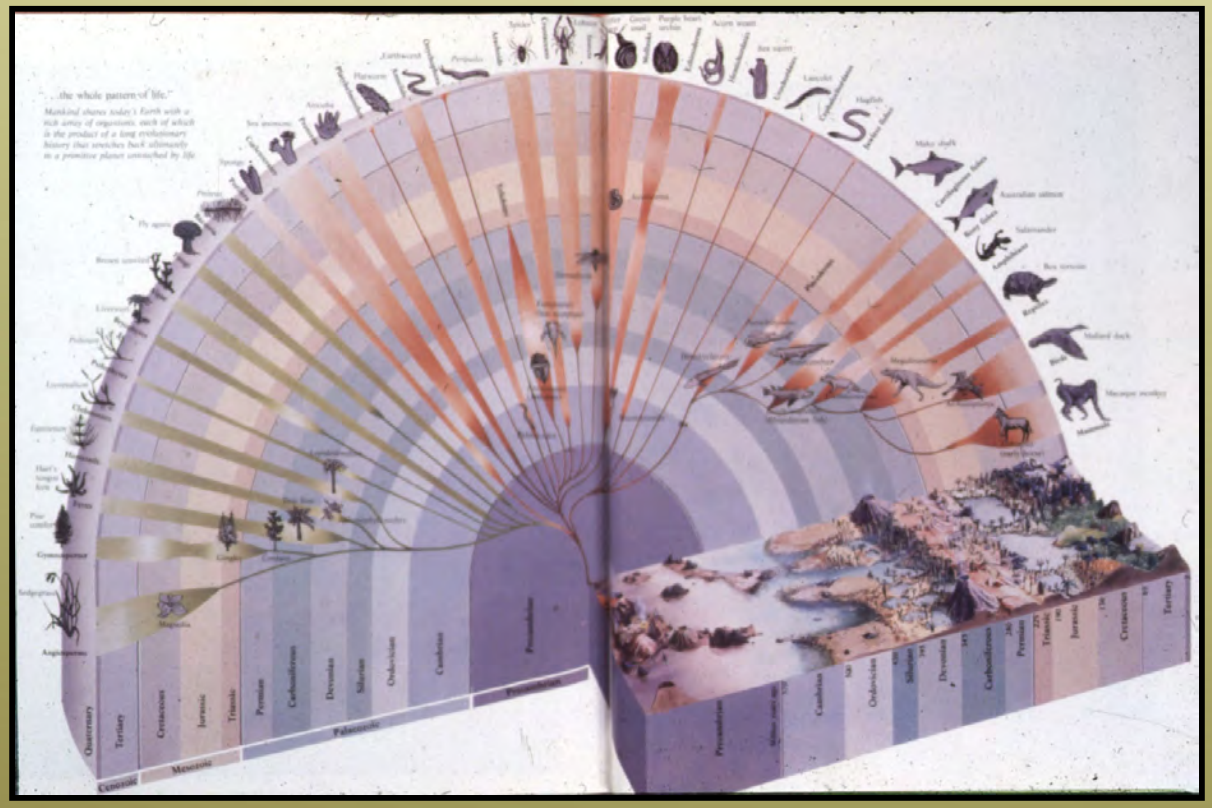
Plate tectonics showing major movements of Africa, India, and Australia



Historical Biogeography

• plants and animals inhabiting the changing environmental setting are not constant either

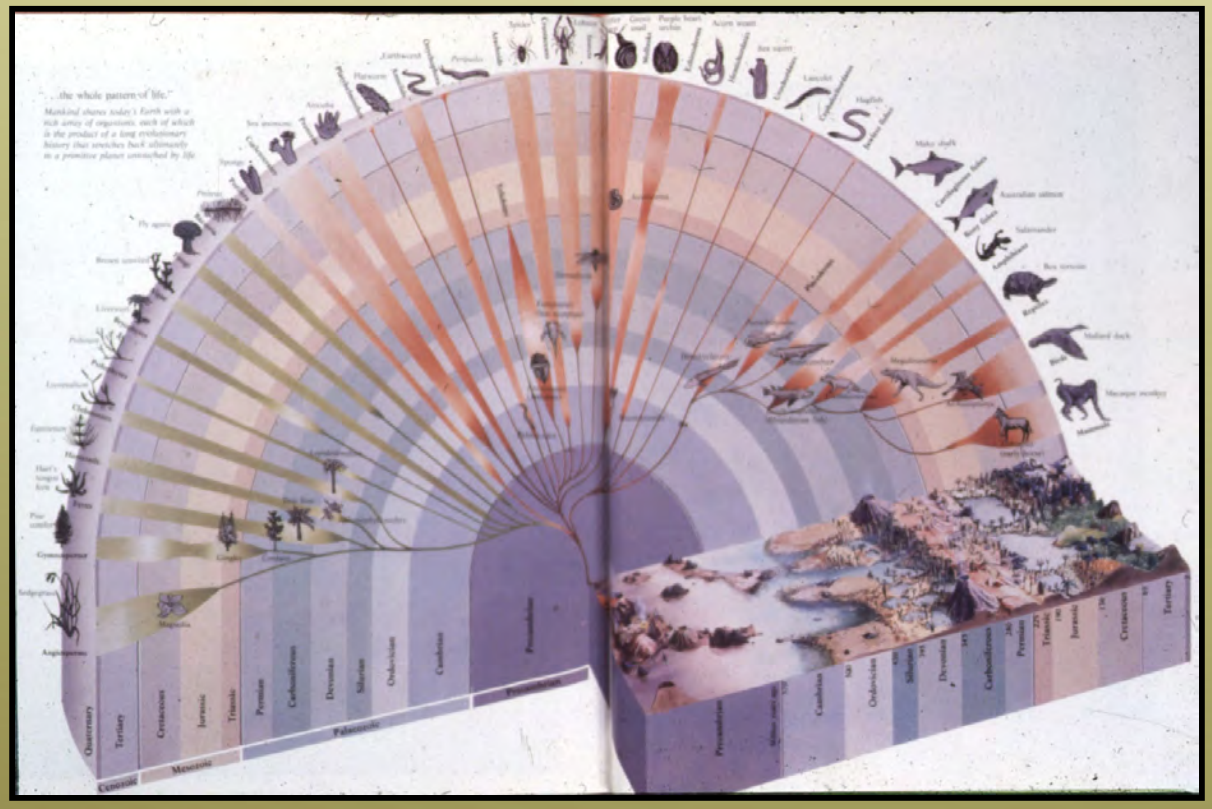
• flora and fauna comprising the vegetation biomes also have changed over time, often as a direct response to the "geological evolution"

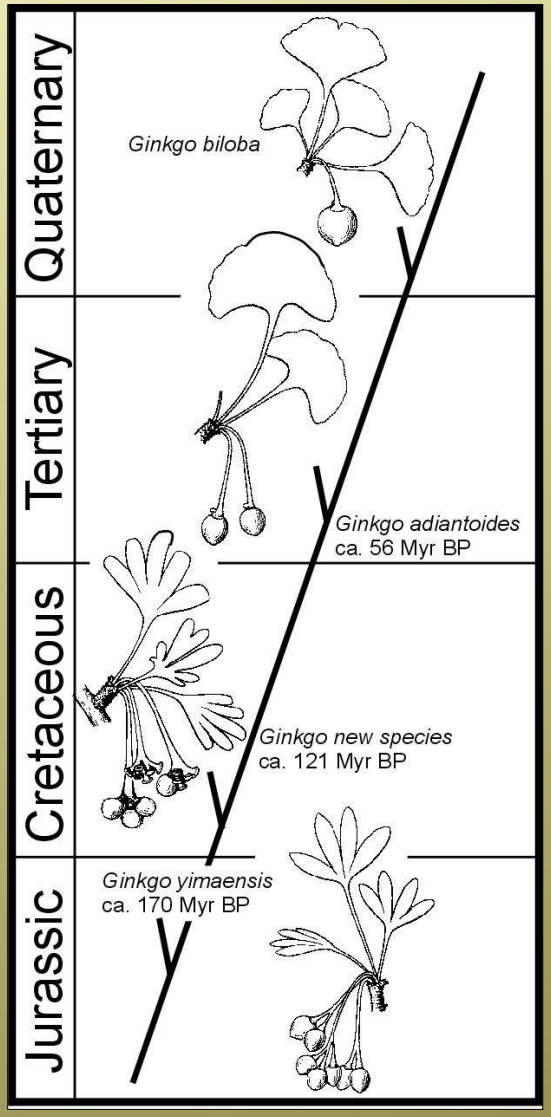


Historical Biogeography

- New species arise by immigration or directly from pre-existing species

- species accumulate variation, adapt, and further diversify

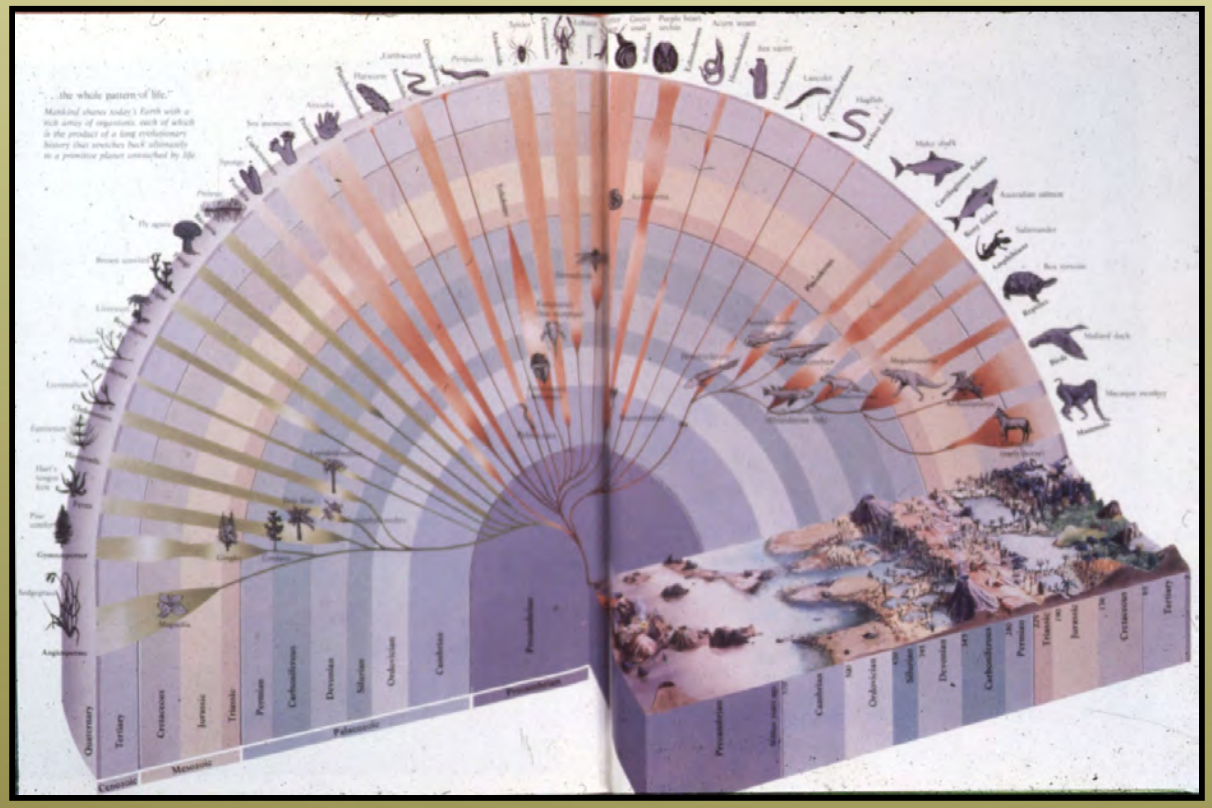


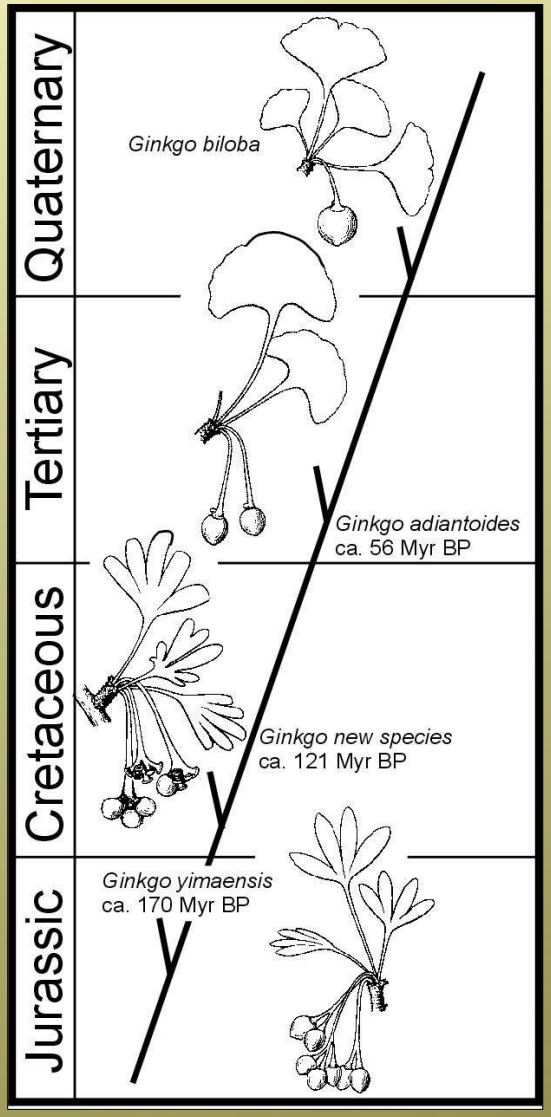


Historical Biogeography

• species go extinct and are replaced by other perhaps more adapted species

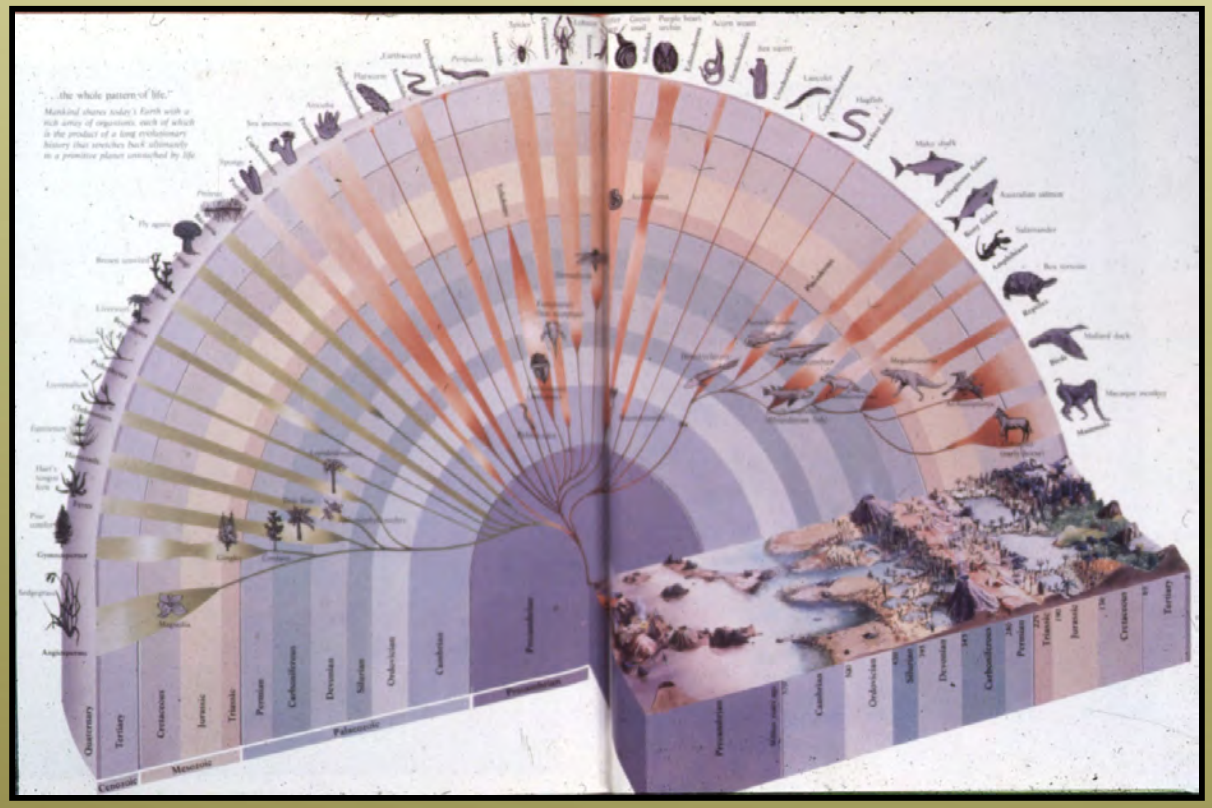
• the same holds true for larger lineages (genera, families) — or taxa.

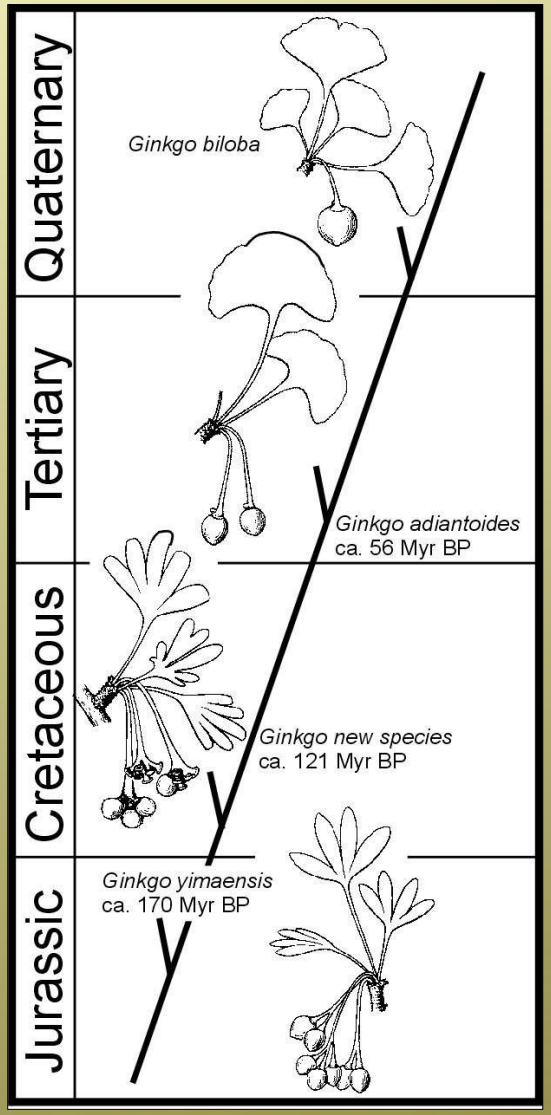




Historical Biogeography

• This biological evolution (taxa evolution) is thus a second important component of the "historical setting" or historical biogeography



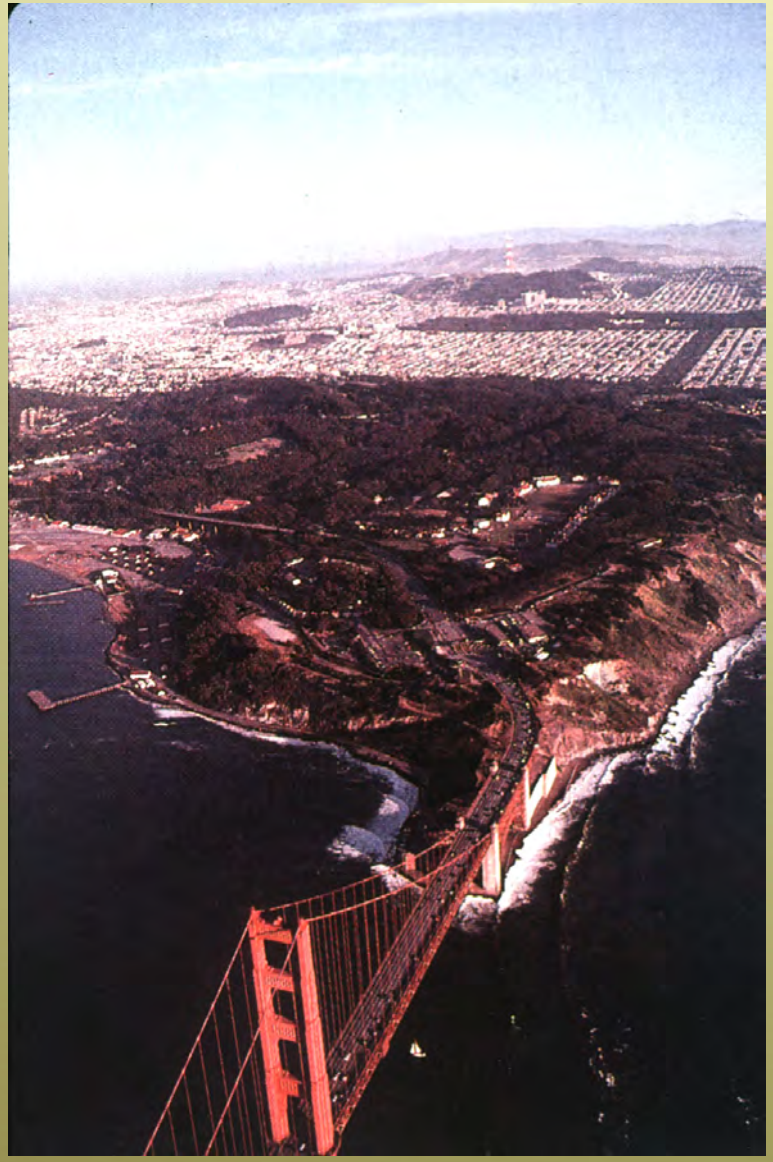


Historical Biogeography

Example 1: *Argyroxiphium sandwicense*

The interplay of geological and biological evolution is critical in understanding why the Haleakala silversword is found in Maui, when and where it or its ancestors came from, and why it is has specific features of morphology, chromosome number, and physiology.

Historical Biogeography



Example 2: *Clarkia franciscana*

The interplay of geological and biological evolution is critical in understanding why, how, and when this clarkia became endemic to serpentine soils in the Golden Gate Park in San Francisco.

Historical Biogeography

Philosophy and Basic Principles — a necessary digression

- Biogeography is not an experimental science, but mostly a **comparative observational** science

- Relationship between **pattern** and **process** — describes much of science, and especially biogeography

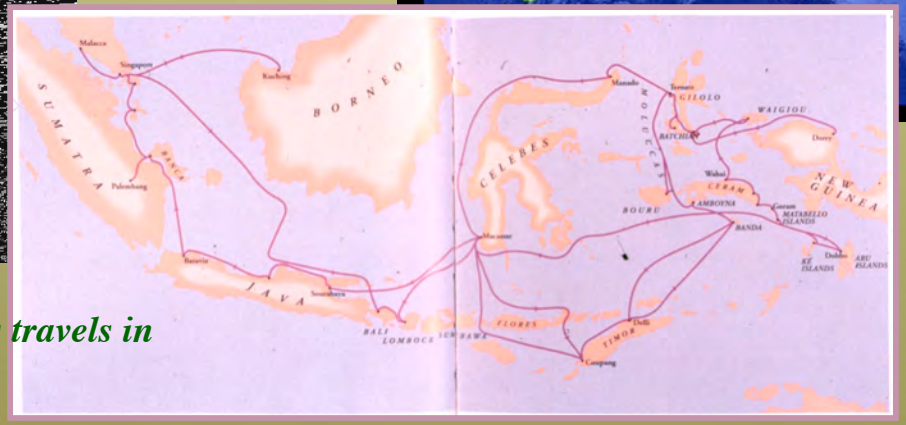
- **Common patterns** often have **common explanations**

Evolution & Biogeography

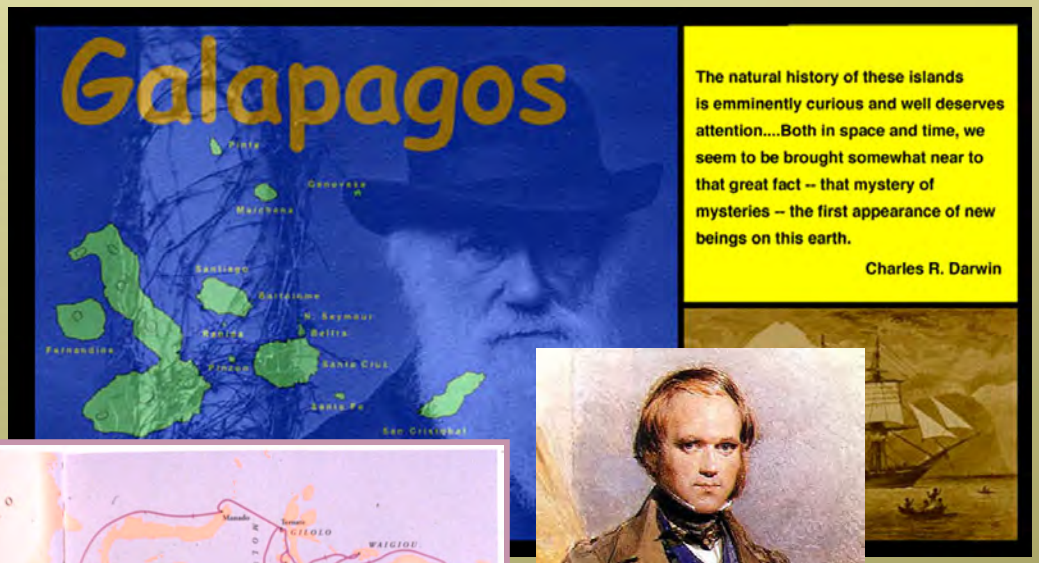
Biogeography is central to the development of evolutionary theory.

The extensive travels of Darwin and Wallace gave important examples of biogeographical distributions, associated variation, and evidence of evolutionary change

Alfred Wallace and his travels in the Malay archipelago



Charles Darwin and his travels in the Galapagos Islands



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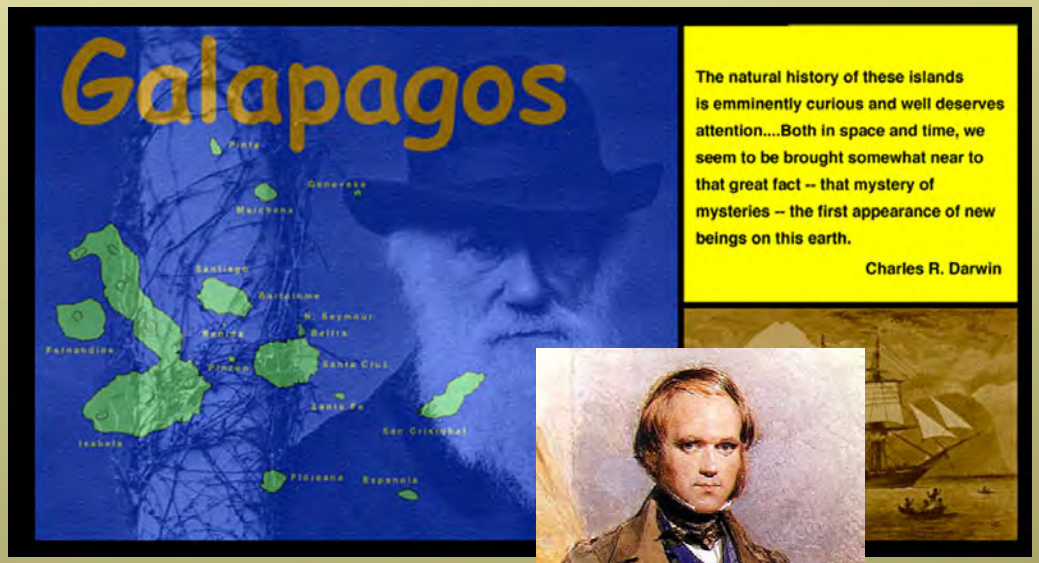
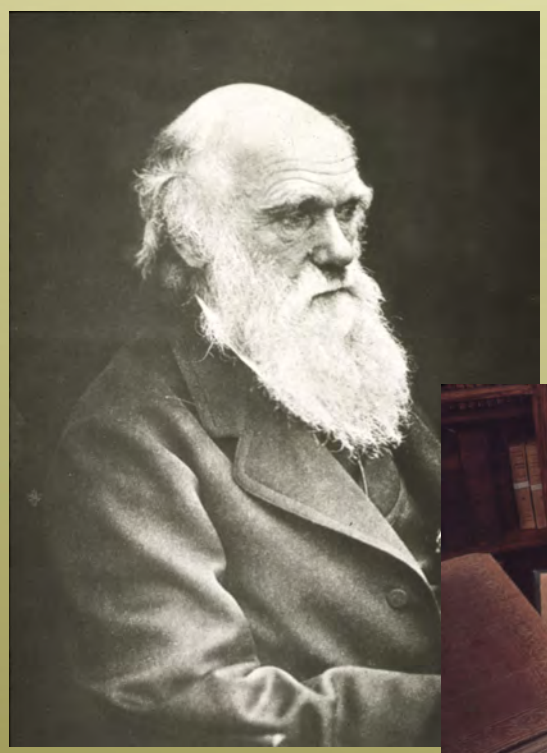


. . .were biogeographical!

Evolution & Biogeography

These biogeographical based examples played a pivotal role in the formulation of both Darwin's and Wallace's evolutionary theories jointly presented in 1858 in London and culminating in the publication of the *Origin of Species* in 1859.



Charles Darwin

Two points about this book

Darwin himself never uses the word "evolution" in *Origin of Species*.

He calls the process

"descent with modification".

Origin of Species

Darwin devoted **two** chapters to biogeography in the *Origin of Species*: Chapter 11 - Geographical Distribution; Chapter 12 - Geographical Distribution *continued*

Evolution

What is it? a definition:

The change of genetic materials
(DNA, genes, chromosomes = Genotype),

and thus also of the physical appearance
(morphology, physiology = Phenotype),

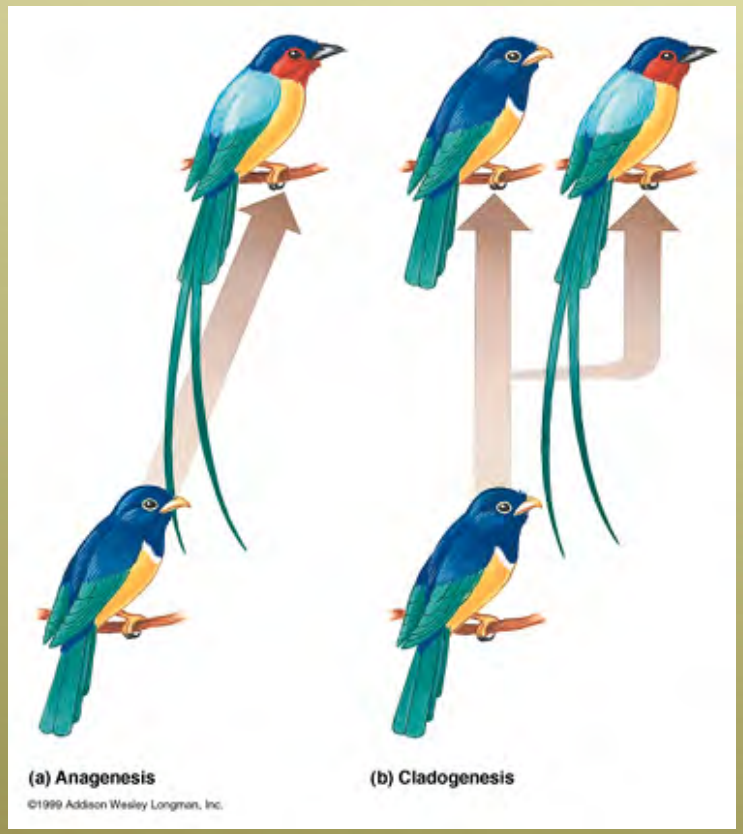
within and among populations and species
through time.

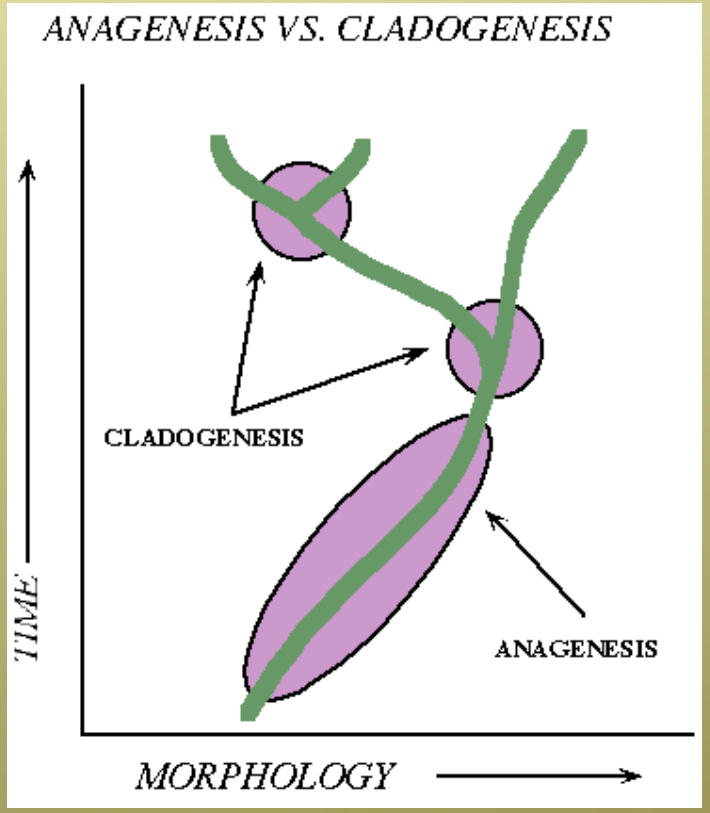
Evolution

What is it? Evolution is often separated into:

anagenesis - evolution within a species lineage — modification (Darwin's term)

cladogenesis - evolution to form new species lineages or **speciation** — descent





Evolution

What does it predict?

It is important to realize that evolution predicts a "**tree**"- like pattern to life; not the Greek "**ladder of life**" pattern. This confusion or mis-application is the basis of a lot of miscommunication in the "evolution-creationist" debate.

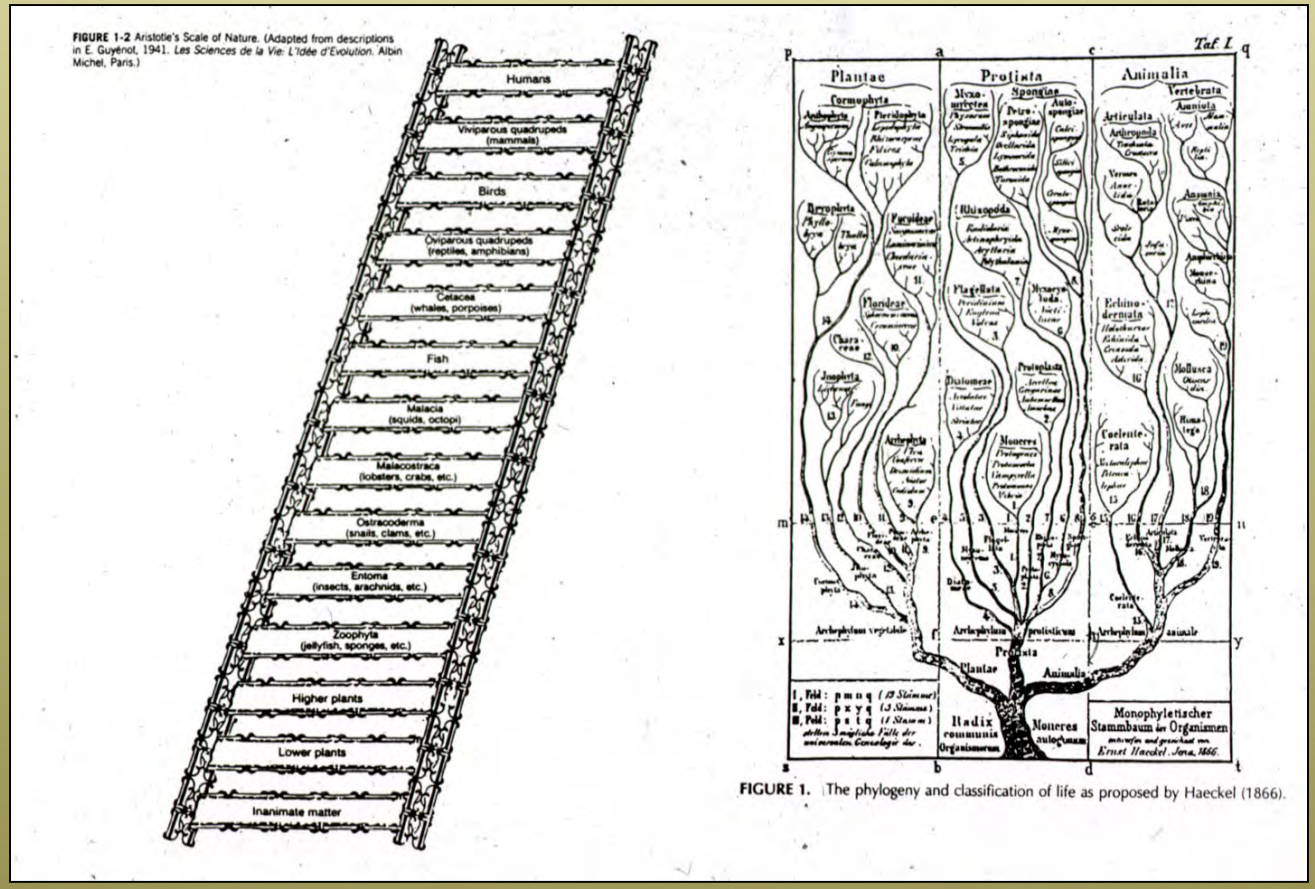


FIGURE 1. The phylogeny and classification of life as proposed by Haeckel (1866).

Evolution

What does it predict?

In the **tree metaphor, all** extant organisms occupy the tips of the branches; in the **ladder metaphor, few** organisms occupy the top rung (*Homo sapiens*) and there is an implicit assumption about passing through one rung to get to the next rung.

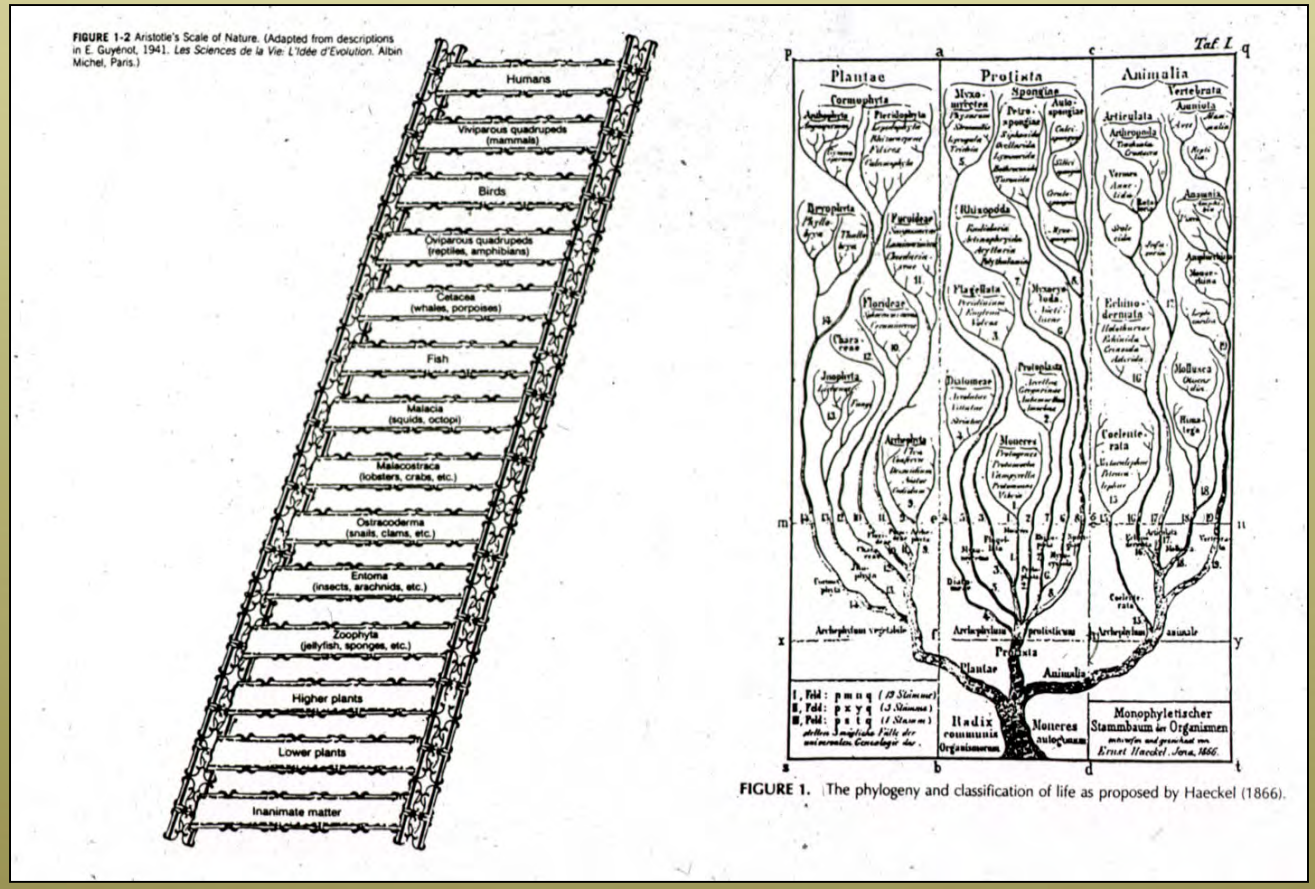
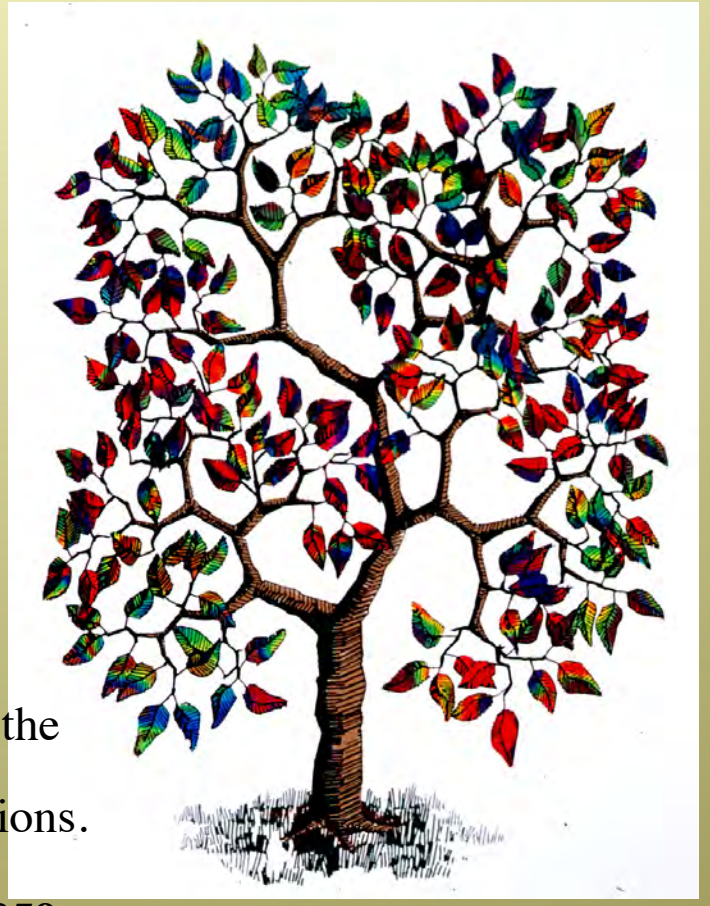


FIGURE 1-2 Aristotle's Scale of Nature. (Adapted from descriptions in E. Guyénot, 1941. *Les Sciences de la Vie: L'Idée d'Evolution*. Albin Michel, Paris.)

FIGURE 1. The phylogeny and classification of life as proposed by Haeckel (1866).

Evolution

The tree metaphor

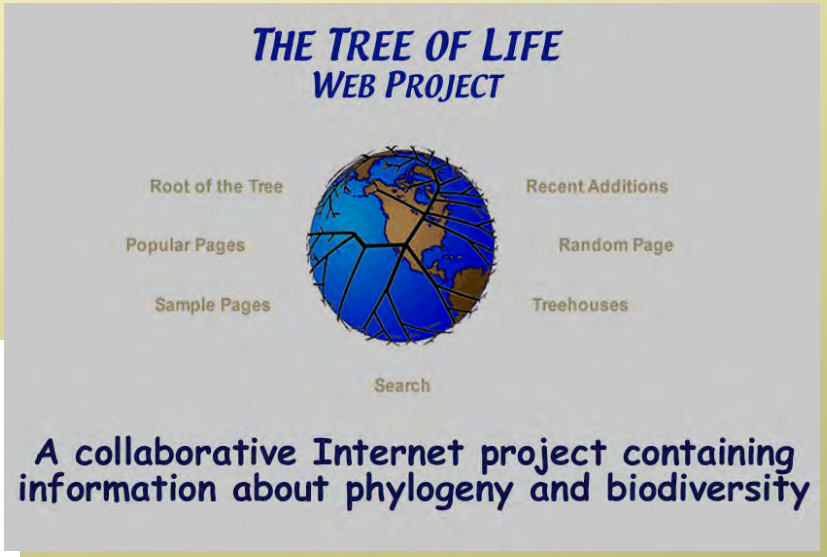


The affinities of all the beings of the same class have sometimes been represented by **a great tree** . . . As **buds** give rise by growth to fresh buds, and these if vigorous, **branch** out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great **Tree of Life**, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications.

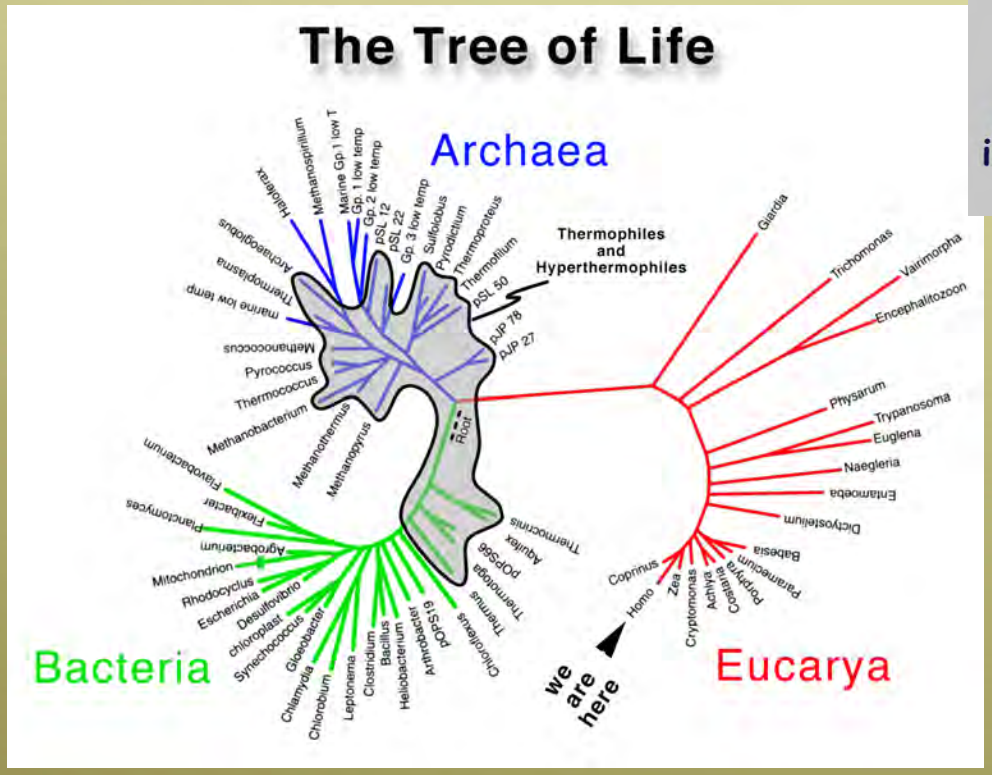
Charles Darwin, 1859

Evolution

The tree metaphor today

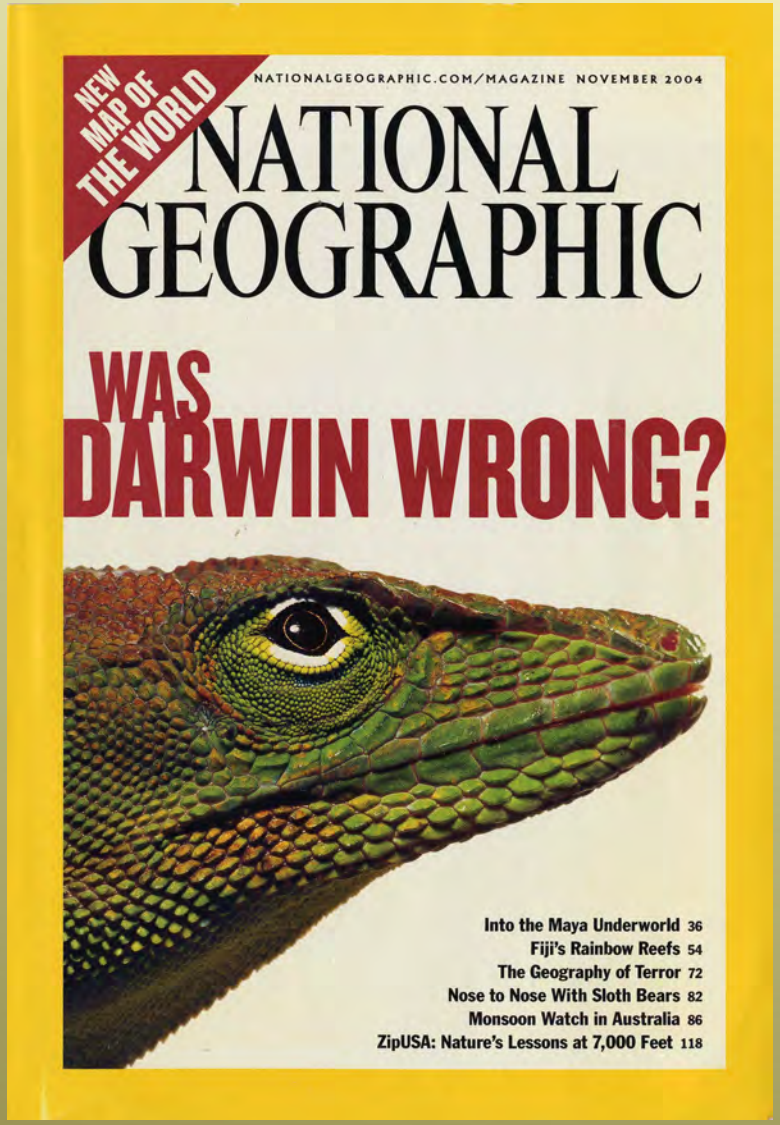


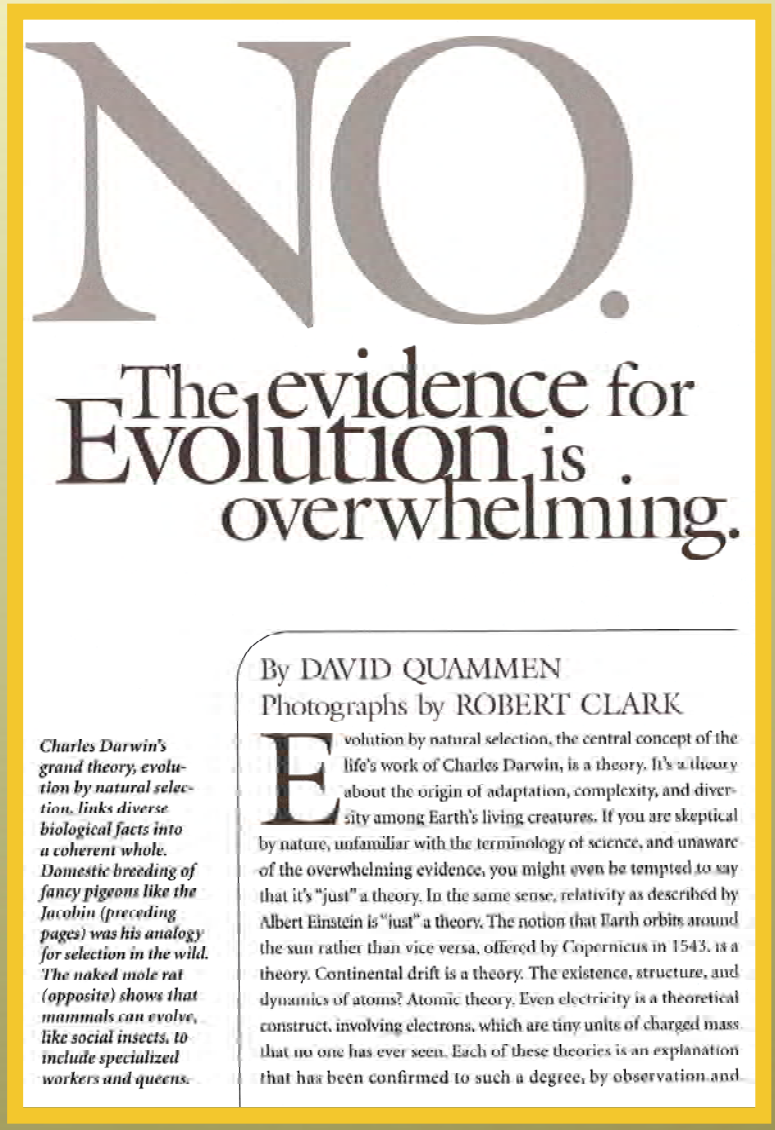
http://tolweb.org/tree/phylogeny.html



The tree or phylogeny is now the standard tool to describe and depict biodiversity at all taxonomic levels

Evidence for Evolution





NO.

The evidence for Evolution is overwhelming.

By DAVID QUAMMEN
Photographs by ROBERT CLARK

Charles Darwin's grand theory, evolution by natural selection, links diverse biological facts into a coherent whole. Domestic breeding of fancy pigeons like the Jacobin (preceding pages) was his analogy for selection in the wild. The naked mole rat (opposite) shows that mammals can evolve, like social insects, to include specialized workers and queens.

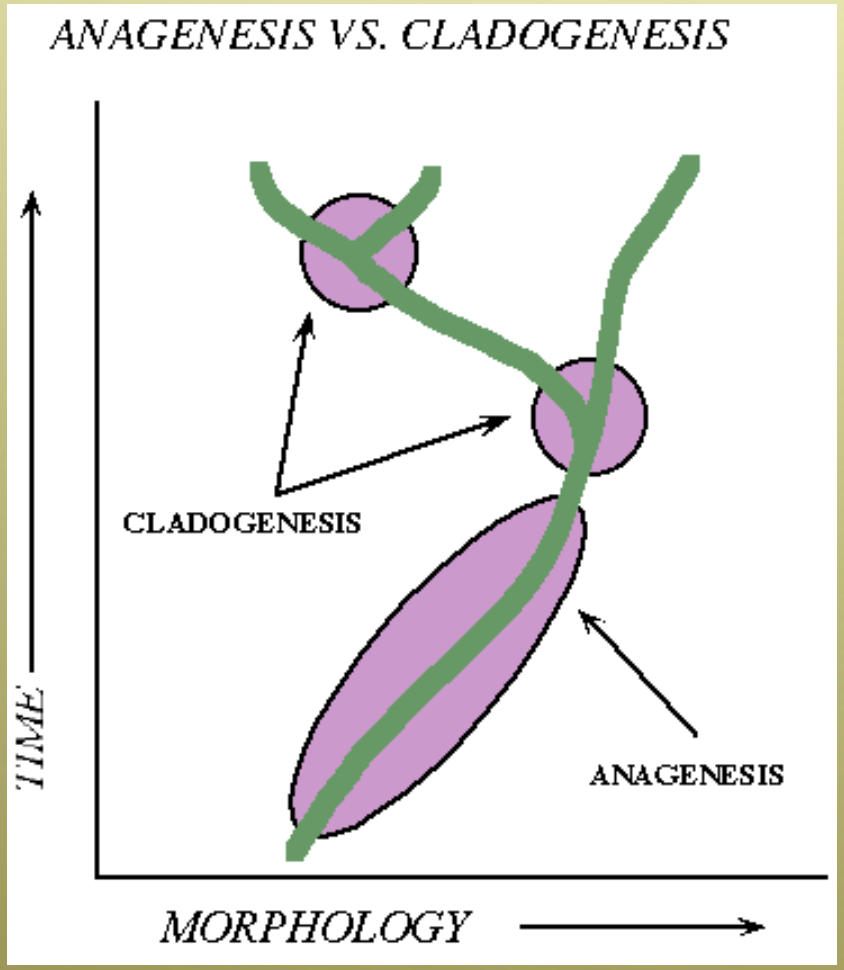
Evolution by natural selection, the central concept of the life's work of Charles Darwin, is a theory. It's a theory about the origin of adaptation, complexity, and diversity among Earth's living creatures. If you are skeptical by nature, unfamiliar with the terminology of science, and unaware of the overwhelming evidence, you might even be tempted to say that it's "just" a theory. In the same sense, relativity as described by Albert Einstein is "just" a theory. The notion that Earth orbits around the sun rather than vice versa, offered by Copernicus in 1543, is a theory. Continental drift is a theory. The existence, structure, and dynamics of atoms? Atomic theory. Even electricity is a theoretical construct, involving electrons, which are tiny units of charged mass that no one has ever seen. Each of these theories is an explanation that has been confirmed to such a degree, by observation and

Evidence for Evolution

* Direct observation — anagenesis, speciation
* Fossil record — "missing links", transitional forms
* Taxonomic pattern of relationships — hierarchical nature
* Biogeography — continental drift, geographical distributions
* Comparative biology — homology vs. analogy
* Vestigial structures — flightlessness, chloroplasts
* Molecular "fossil" record — DNA and protein sequencing

Evidence for Evolution

Direct observation — anagenesis, speciation

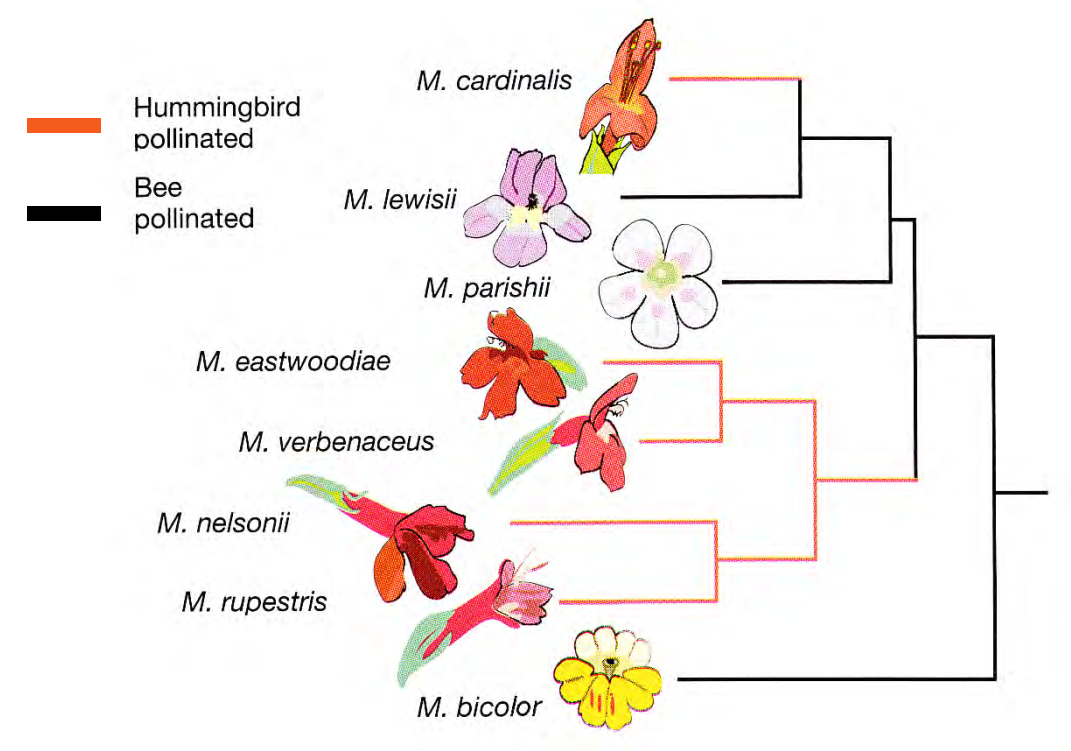


The splitting of a species into new species, speciation or cladogenesis, has been extensively studied in plants

The speciation process has been studied at incipient stages as well as at recently occurring stages

Evidence for Evolution

Direct observation — anagenesis, speciation



The splitting of a species into new species, speciation or cladogenesis, has been extensively studied in plants

The speciation process has been studied at incipient stages as well as at recently occurring stages

One of the best studied systems involves two western U.S. monkeyflowers *Mimulus cardinalis* (hummingbird pollinated) and *M. lewisii* (bee pollinated) — a pair of recently speciated species

Evidence for Evolution

Direct observation — anagenesis, speciation

These two species and their origin have been studied by looking at their DNA, ecological niches, and natural selection via pollinator pressures.

Importantly, using crosses and detailed genetic analyses, the quite different floral morphologies (bird vs. bee pollinated syndromes) have been shown to be due to just a few genes — do not have invoke long periods of time or many, small incremental changes.

Evidence for Evolution

Taxonomic pattern of relationships — hierarchical nature

An Example of an Hierarchical Classification System for *Solidago canadensis* (Canada goldenrod)

taxon	*-ending*	*rank*
Magnoliophyta	-phyta	Phylum
Magnoliopsida	-opsida	Class
Asterales	-ales	Order
Asteraceae	-aceae	Family
Asteroideae	-oideae	Subfamily
Astereae	-eae	Tribe
Solidago		Genus
S. canadensis		Species

• Species do not vary in a random manner . . .

. . . but exhibit characteristics that allow them to be placed in larger groups (taxa) sharing subsets of these characters.

Evidence for Evolution

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• Species do not vary in a random manner . . .

. . . but exhibit characteristics that allow them to be placed in larger groups (taxa) all sharing these characters.

• This pattern of hierarchical structure is predicted by evolution.

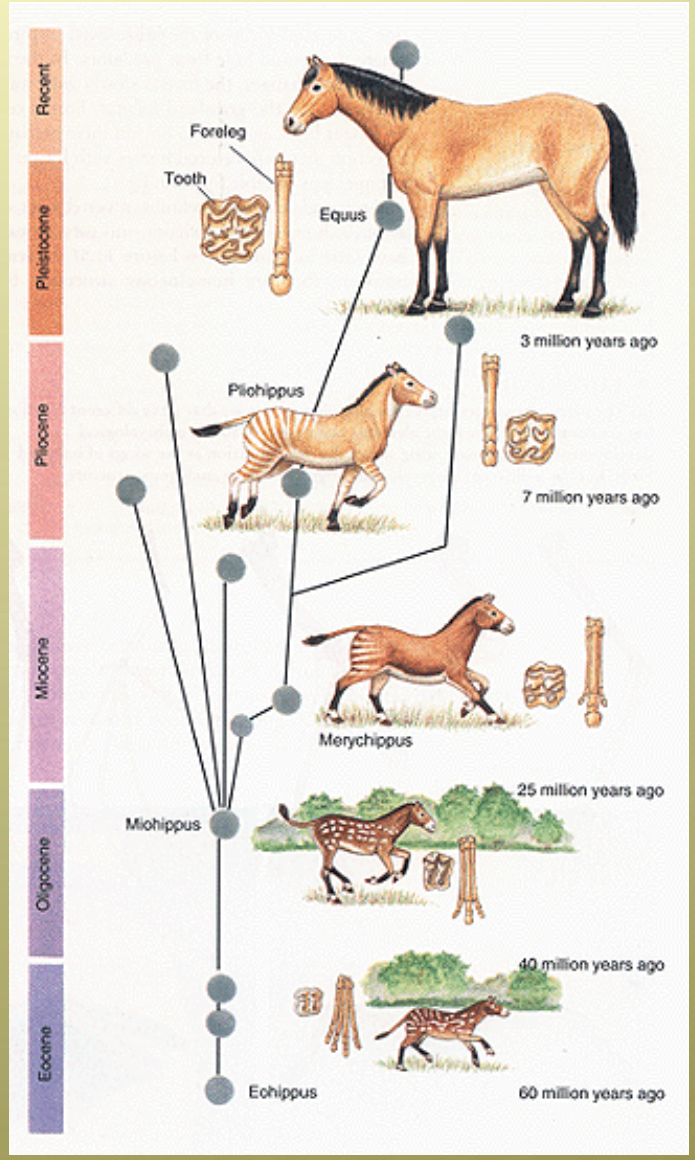
Evidence for Evolution

Fossil record — transitional forms, "missing links"

Fossil record provides amazing detail that supports evolutionary interpretations – e.g., horse lineage and the whale lineage.

A major misconception in the "evolution vs. creationist" debate is the idea that there has to be direct links between forms.

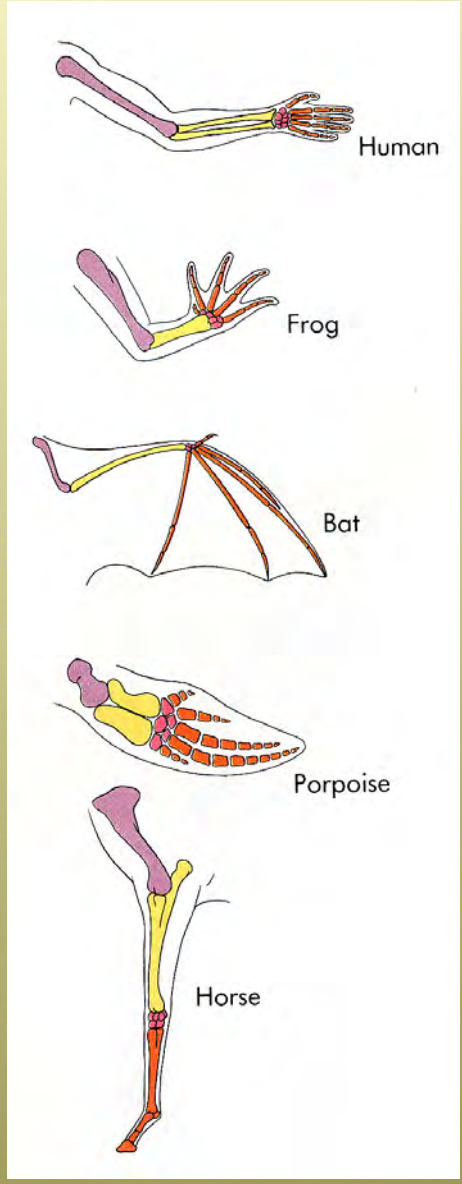
This misconception generates the accusation of "missing links". These "missing links" are indeed there but not necessarily of the form looked for because of naïve assumptions.



Evidence for Evolution

Character divergence — homology vs. analogy

Evolution thus predicts that species coming from a common ancestor should share **homologous** characters — derived from the same structure(s) — but that they will show **divergence** in these characters through time



grasping

leaping

flying

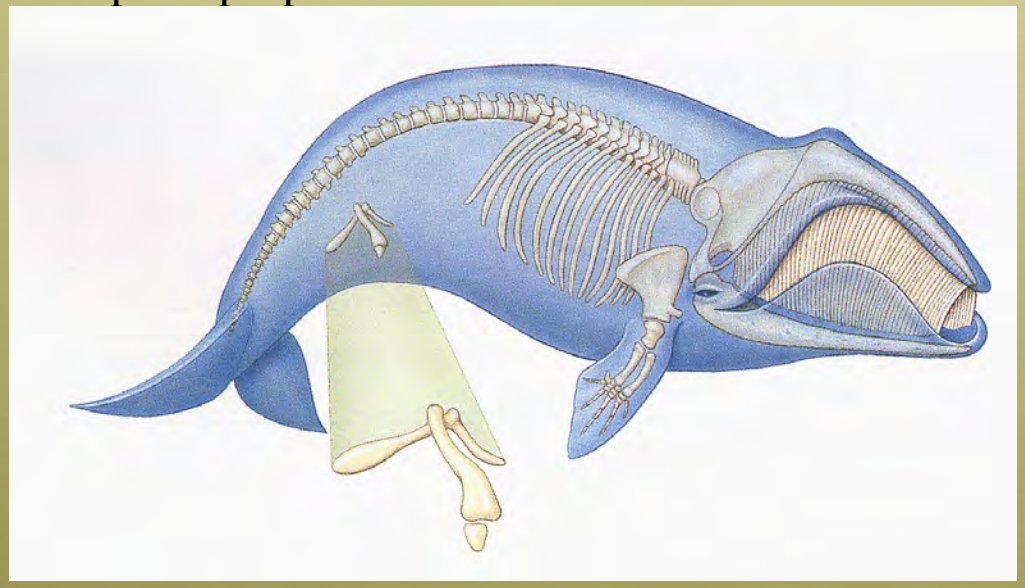
swimming

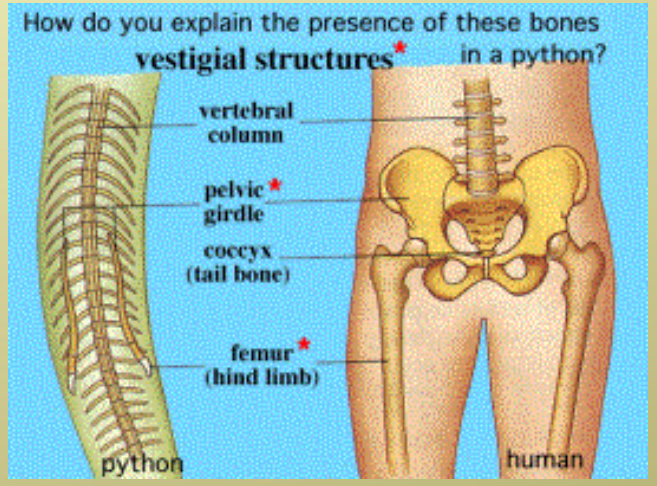
running

Evidence for Evolution

Vestigial structures — homology vs. analogy

Evolution would also predict that species occupying very distinct environments from that of a common ancestor might show **vestigial** structures — structures obtained from a common ancestor but no longer needed for the original adaptive purpose.





The **pelvic girdle** seen in reptiles and mammals as an adaptation for support in tetrapods, is vestigial in snakes and whales — it is a "fossil" footprint of their ancestry and serving no function today in crawling or swimming tetrapods.

Evidence for Evolution

Vestigial structures — homology vs. analogy

Evolution would also predict that species occupying very distinct environments from that of a common ancestor might show **vestigial** structures — structures obtained from a common ancestor but no longer needed for the original a

In the same manner, the parasitic and non-green dodders retain "fossil" **chloroplasts** (photosynthetic organelles) in their cells as a vestigial structure inherited from a common ancestor with morning glories — although the plastid is very reduced and much of the plastid DNA has been lost

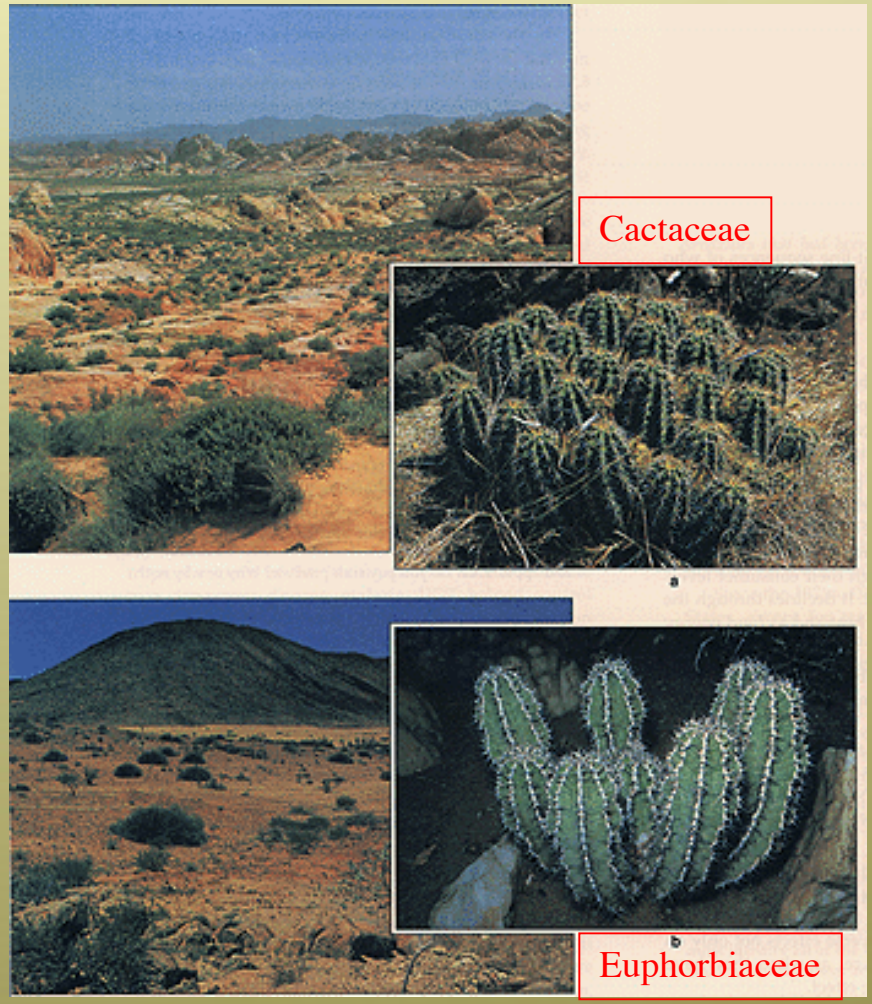
Evidence for Evolution

Biogeography and Comparative Biology — homology vs. analogy

Our discussion of *Vegetation vs. Flora* has already provided numerous examples of unrelated organisms showing **convergent** (**analogous**) features as responses to similar environmental pressures

Similar body shapes and structures have evolved in the North American desert cacti . . .

and separately in the euphorbias in southern African deserts

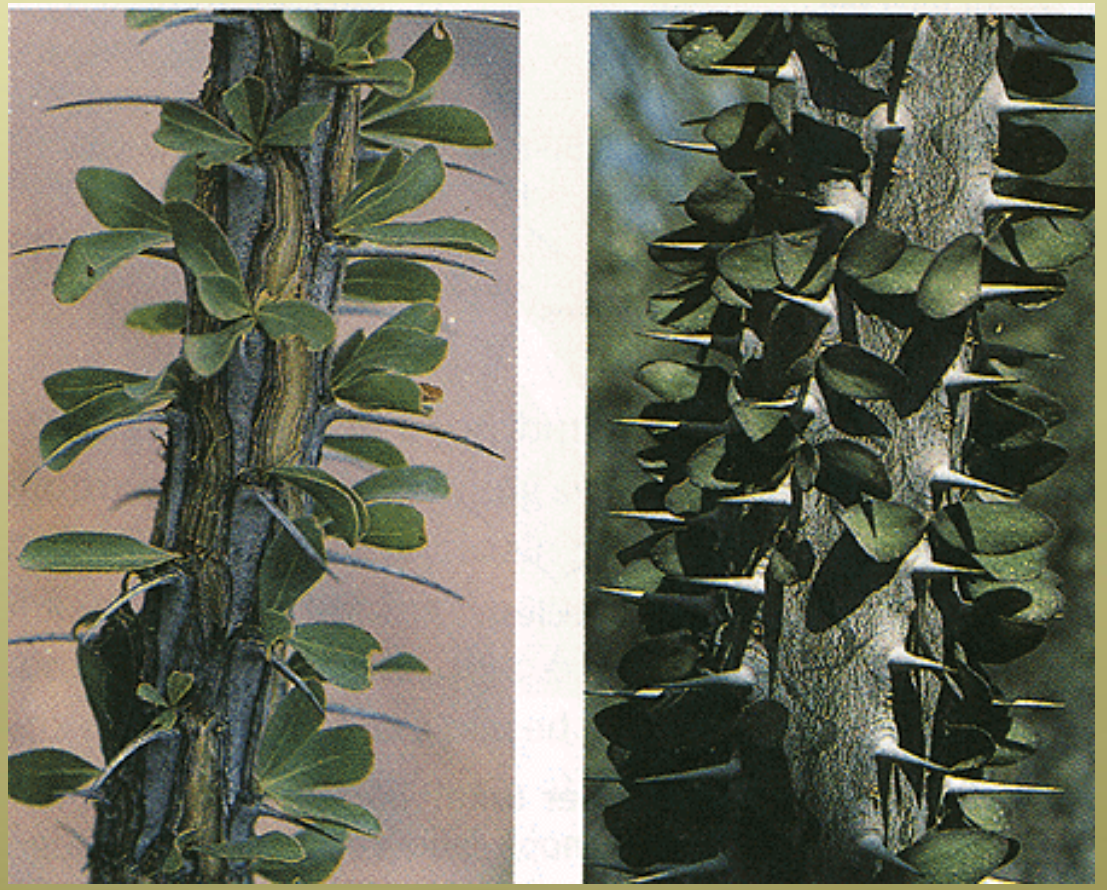


Evidence for Evolution

Biogeography and Comparative Biology — homology vs. analogy

Convergent structures in the ocotillo (left) from the North American deserts . . .

and in the allauidia (right) from Madagascar.

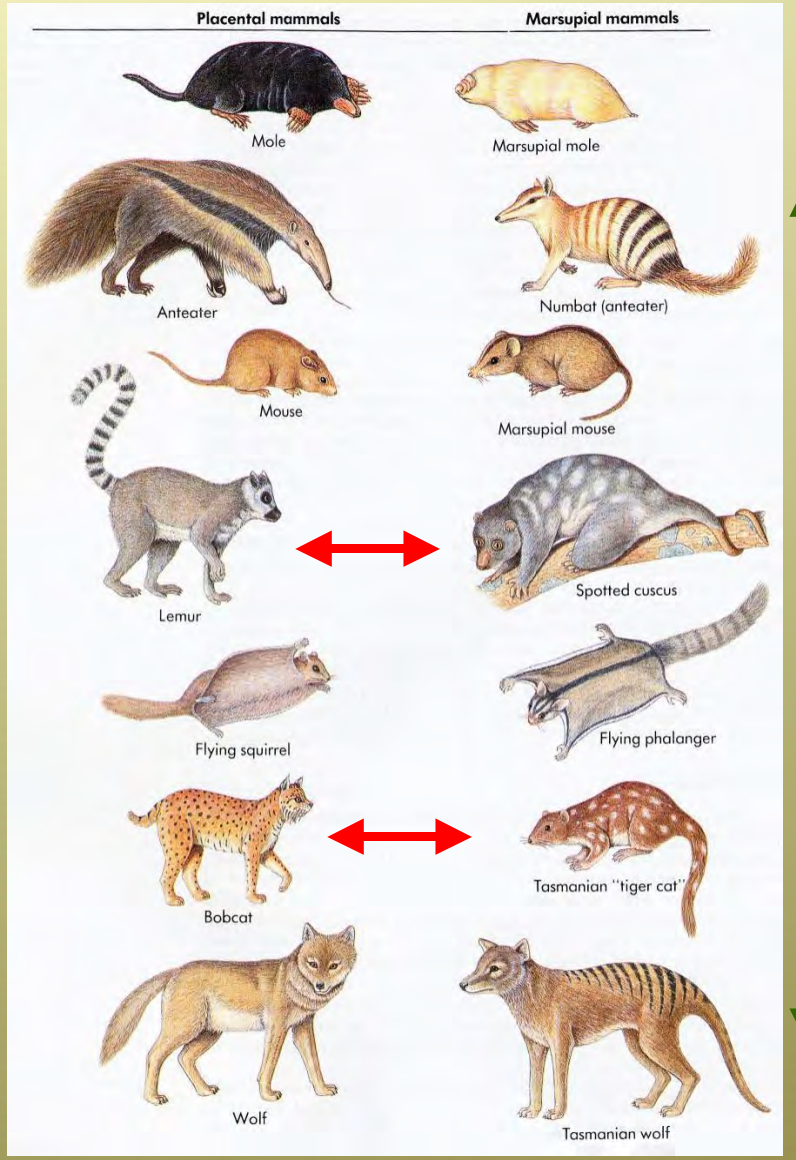


***Foquieria* - Foquieriaceae** ***Allauidia* - Didieriaceae**

Evidence for Evolution

Biogeography and Comparative Biology

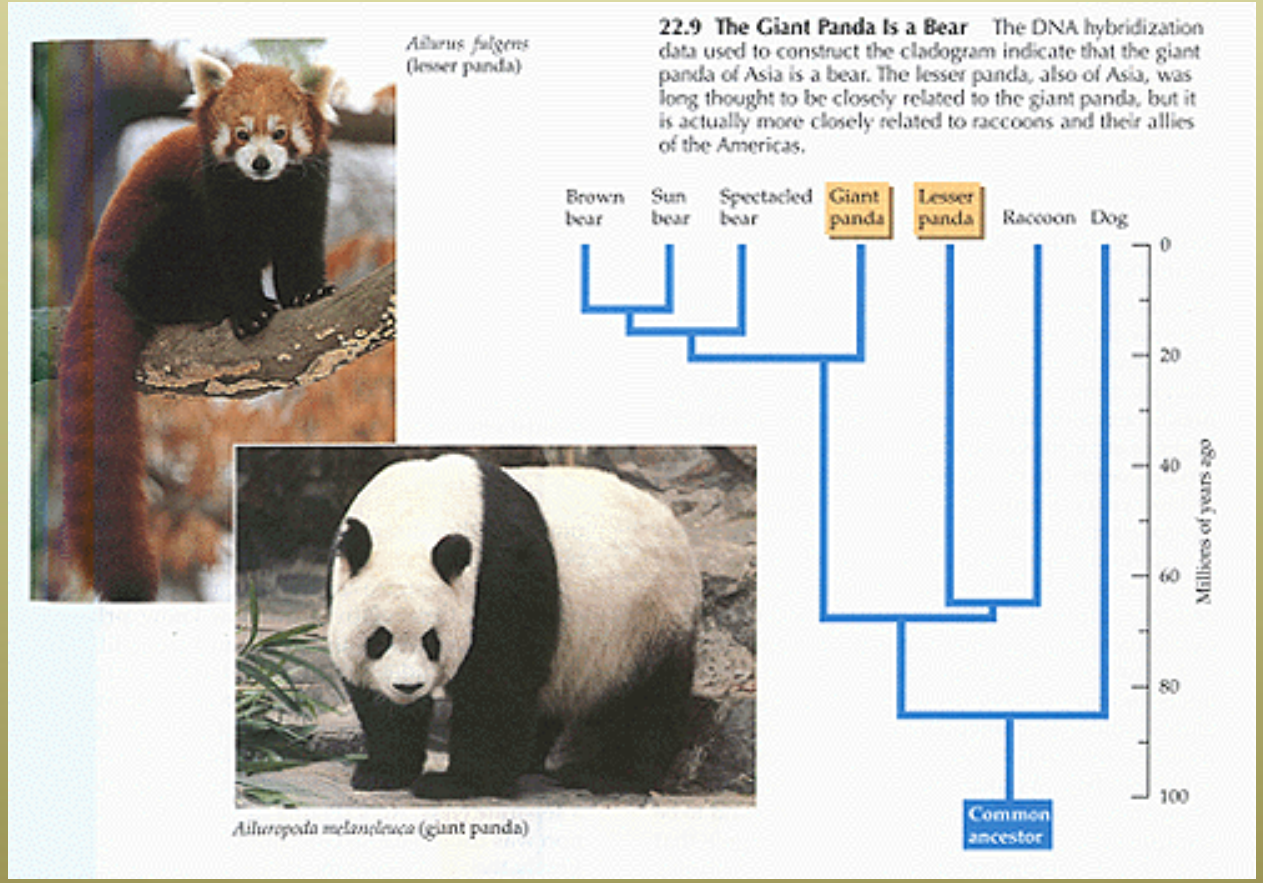
The convergence of mammals (marsupials) in Australia vs. the placental mammals elsewhere in the world is one of the most spectacular examples of biogeographical based **convergences** in animals as well as **divergences** within each lineage



Evidence for Evolution

Molecular "fossil" record — phylogenetic trees

The use of DNA to produce (estimate) phylogenetic relationships among organisms has revolutionized our understanding of character evolution



Evidence for Evolution

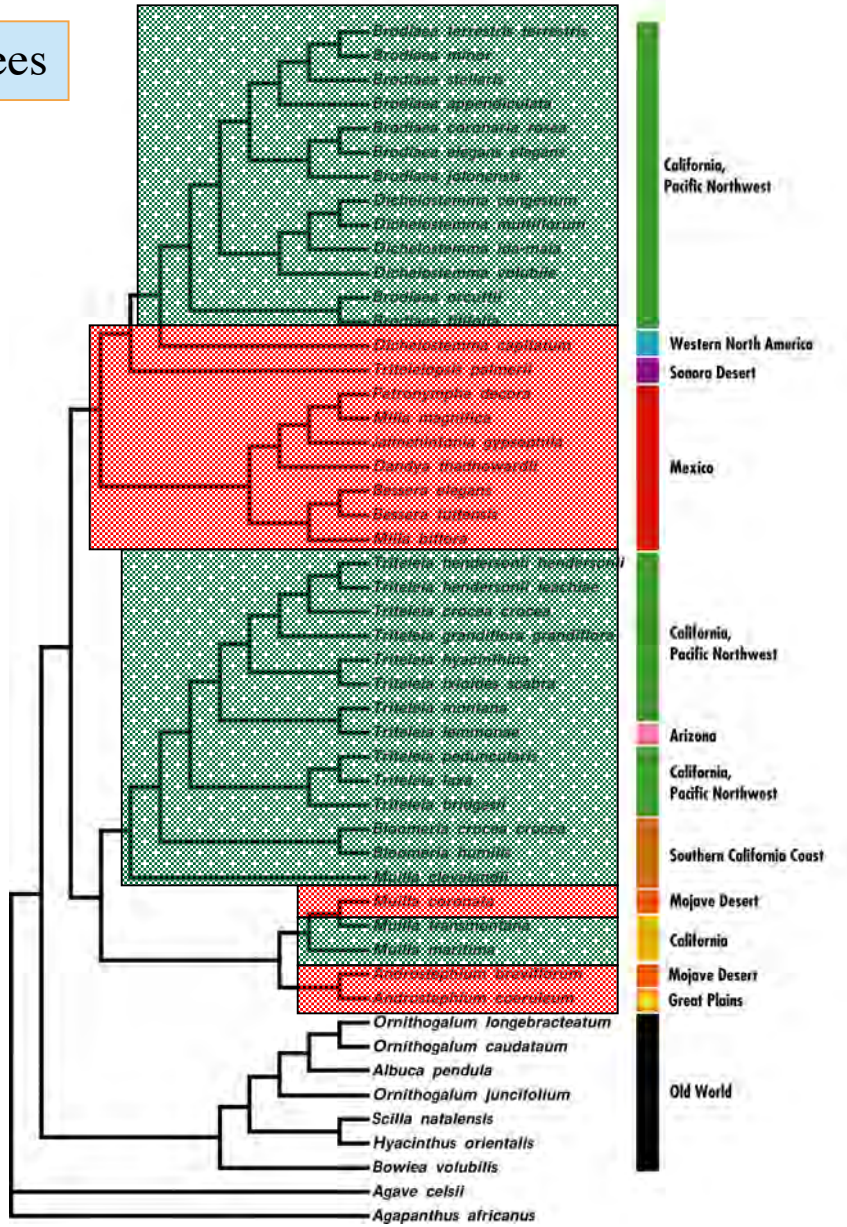
Molecular "fossil" record — phylogenetic trees

The *Brodiaea* complex (Themidaceae) in California and Madrean Region of SW N. Amer.

Brodiaea terrestris

Bessera elegans

(Pires and Sytsma 2002)



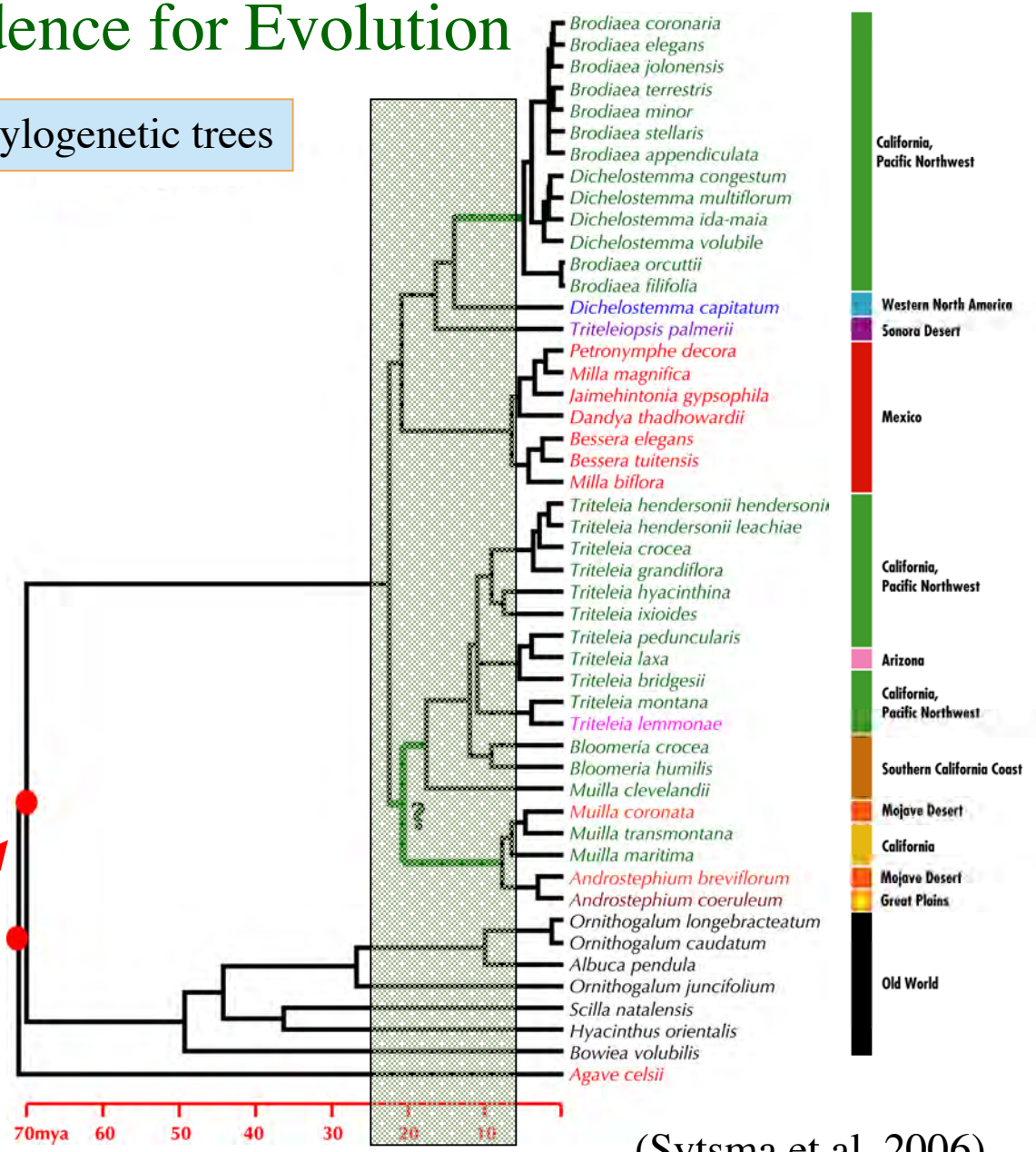
Evidence for Evolution

Molecular "fossil" record — phylogenetic trees

Chronogram of Themidaceae and Hyacinthaceae

• origins of California Floristic Province lineages (2 or 3) are Miocene

Fossil fixed ages of 71.5 and 70.5 mya



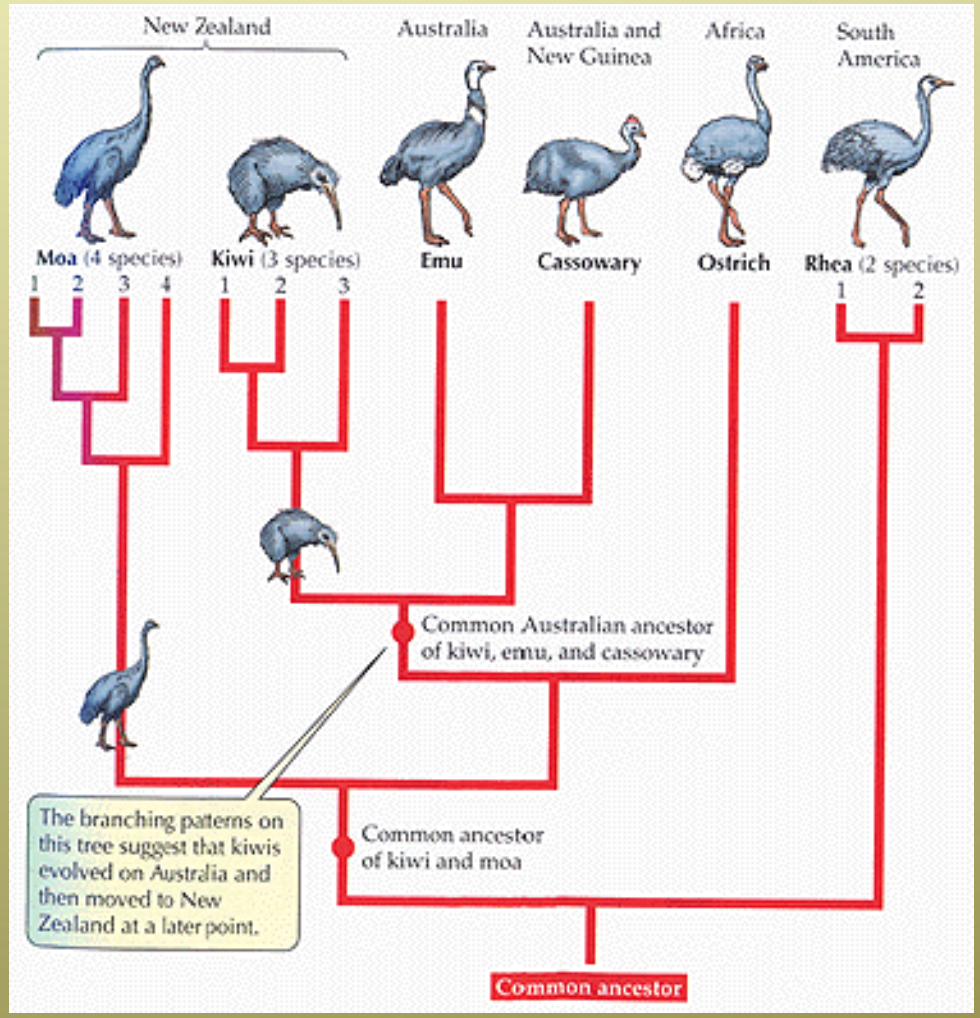
(Sytsma et al. 2006)

Evidence for Evolution

Molecular "fossil" record — phylogenetic trees

The use of DNA to estimate phylogenetic relationships among organisms has also revolutionized biogeography

Phylogenetic trees not only provide strong hypotheses of biological relationships but they can also give estimates of relationships of the areas which the taxa occupy



Evidence for Evolution

Molecular "fossil" record — phylogenetic trees

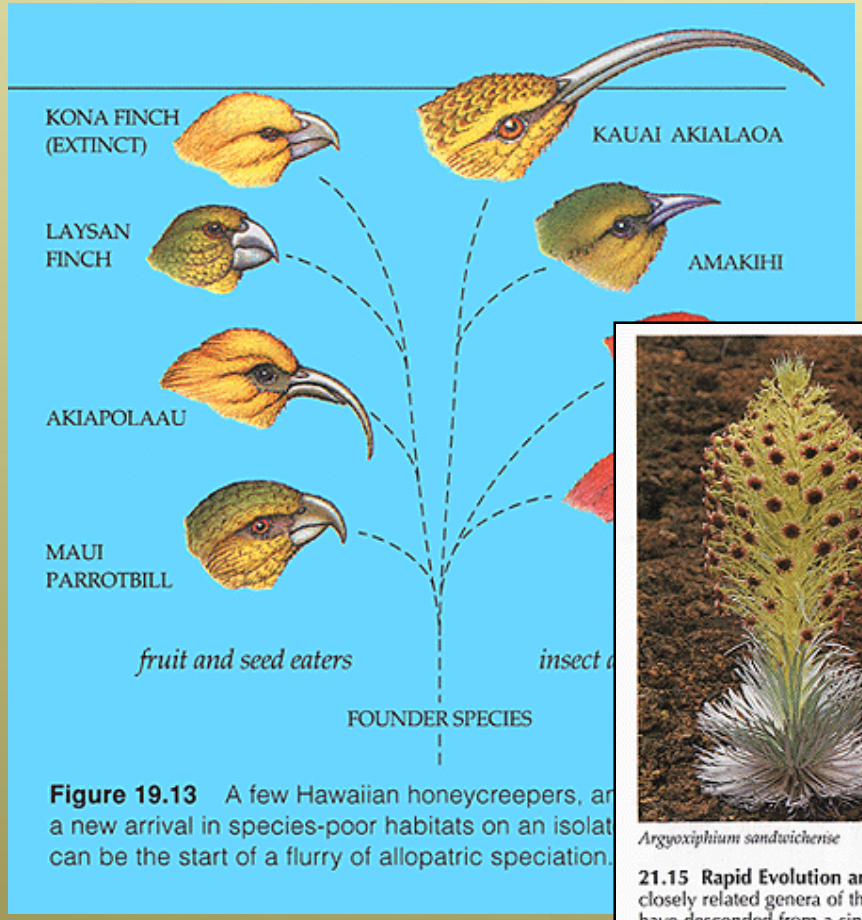


Figure 19.13 A few Hawaiian honeycreepers, ar
a new arrival in species-poor habitats on an isolat
can be the start of a flurry of allopatric speciation.

Hawaiian honeycreeper alliance

As we will see, molecular phylogenetics will be critical in unraveling "*adaptive radiations*" in island biogeographic settings

Hawaiian silversword alliance

Argyroxiphium sandwicheense

Wilkesia gymnoxiphium

Dubautia laxa

21.15 Rapid Evolution among Hawaiian Plants Three closely related genera of the sunflower family are believed to have descended from a single ancestor, a tarweed that colonized Hawaii from the Pacific coast of North America. Their rapid evolution makes them appear more distantly related than they actually are.