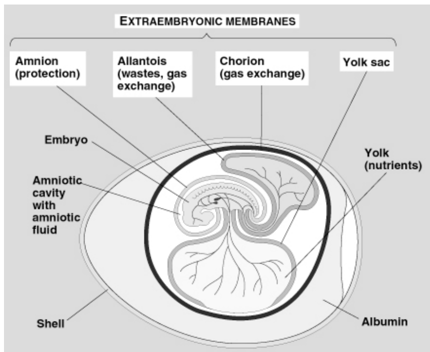
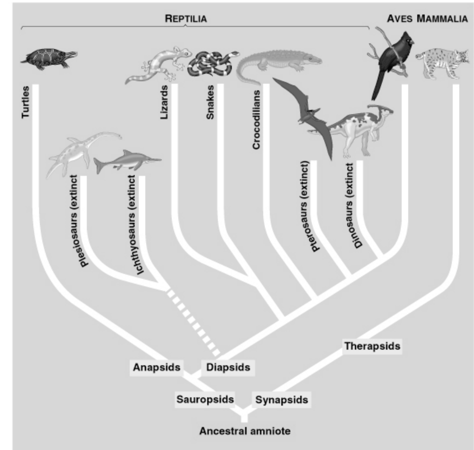
The Amniotes: "Reptiles", birds, and mammals

The amniotic egg allowed tetrapods to become completely terrestrial. In an amniotic egg, a membrane called the amnion surrounds the embryo and creates a fluid-filled cavity in which it develops. Other membranes aid in gas exchange, protection, and removal of wastes.

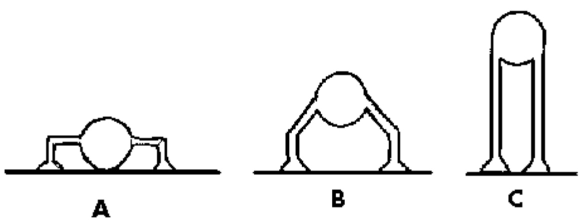


Phylogeny of the Amniotes shows a non-monophyletic Reptilia, since birds and possibly even mammals were descended from the shared ancestor to all "reptiles".

Major lineages include turtles; giant aquatic reptiles (extinct); a clade of lizards and snakes; crocodilians, pterosaurs; birds; and the dinosaurs.

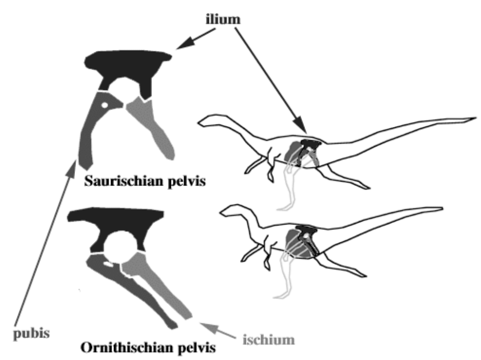


Early tetrapod amniotes also evolved internal fertilization, more protective skin, stronger locomotive and respiratory muscles, and more upright limb attachment that was better suited for walking.



Sprawling Semi-erect Erect

Dinosaurs were abundant and diverse during the Jurassic and Cretaceous periods of the Mesozoic (up to 65 MYA). There were two main lineages: lizard-hipped dinosaurs (saurischians, including Tyrannosaurus, Brontosaurus, and birds) and bird-hipped dinosaurs (ornithiscians, including Ankylosaurus, Stegosaurus, and Triceratops). Each group was probably monophyletic.



In birds and Ornithischians, the pubis of the pelvis points backwards; however, note that birds are actually more closely related to saurischians!

Pterosaurs and birds: two independent origins of powered flight in tetrapods

Some pterosaurs were enormous, with wingspans over 25 feet; however, they did not have feathers, and the arrangement of bones in the wings is different from that in birds.

Archaeopteryx

a fossil pterosaur

Birds, on the other hand, have feathers and are endothermic. Bird feathers are modified scales; the original function of feathers and of wings may have had more to do with endothermy than with flight.

Modern birds are extremely diverse: morphologically, behaviorally, and ecologically. Approximately 9000 species are currently known.






About 65 million years ago, the dinosaurs went extinct... *along with ~70% of the world's species*

In rocks of about that age, the presence of unusually high amounts of the element iridium suggests that a catastrophic astronomical event occurred on Earth around that time.

Scientists now believe that an giant asteroid must have struck the earth near the end of the Cretaceous. A potential impact site is Chicxulub off the Yucatan peninsula in Mexico.

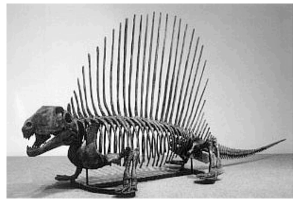
Such an impact would have had major lasting effects on the environment, including changes in temperatures, light levels, and the chemistry and quality of air and water.

Although mammals were already present on Earth by the time of the asteroid impact (having evolved from reptile-like ancestors), the resulting mass extinction freed up resources and habitats that allowed mammals to undergo a massive species radiation once favorable conditions were restored to Earth.

The Evolution of Mammals

Mammals were around long before the first dinosaurs and birds.

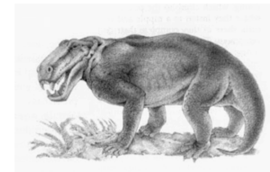
Mammals evolved in the Permian from reptilian animals that were probably related to the **pelycosaurs**, such as Dimetrodon. **Pelycosaurs were not dinosaurs.**



Pelycosaurs may have been partly **endothermic**, using their dorsal sails to collect and disperse radiant heat.

Note the sprawled limbs of pelycosaurs, emerging from the sides of the body

The next mammal-like 'reptiles' to evolve from pelycosaur ancestors were the **therapsids**. These animals were increasingly endothermic and walked more erect. They may have even had **hair**.



Even before the first dinosaurs appeared, therapsids evolved into the earliest mammals. In addition to endothermy, erect legs, and body hair, mammals characteristically have:

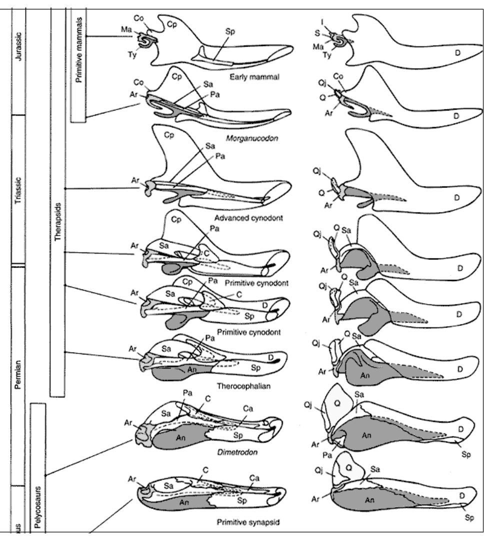
- a **four-chambered heart**
- **milk glands** and other glands in the skin
- specialized **differentiated teeth**
- a lower **mandible** (jaw) made up of only a **single bone**
- imperative **parental care**

The evolution of the mammalian jaw from the reptilian jaw also resulted in the appearance of the three bones in the mammalian inner ear:

malleus (articular);
incus (quadrate)
stapes (angular)

This represents one of the most famous transitional series in evolutionary biology.

It is also an example of the "**tinkering**" approach of evolution



The **monotremes** are an extant group of mammals that still lay eggs, like the early mammals did. The only living representatives are the **echidnas** and the **duck-billed platypus**.

Monotremes have both reptile-like and mammal-like traits.

Reptile-like traits of monotremes:

Egg laying
Sprawled limbs
Single excretory canal (cloaca)
Torpor in low temperatures
No teats; milk is excreted from
glands in the skin, and the young
lick the milk from the skin and fur

There are over 4000 species of mammals living today.
Other than the monotremes, all mammals belong to one of two monophyletic lineages: the **marsupials** and the **placentals**.

These groups differ primarily in the anatomy and behavior involved in **gestation**, giving birth, and caring for the young.

In marsupials, the young are born extremely tiny and incompletely developed. They are nursed on nipples within an abdominal pouch that exists only in marsupials.

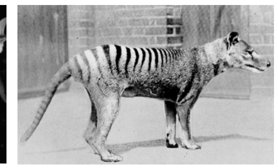
In placentals, the young are gestated for much longer within the uterus, and are born more completely developed.

Marsupials include (o)possums, kangaroos, wallabies, wombats, koala bears, sugar gliders, bandicoots, and smaller animals.

In South America, they were largely out-competed by the placental mammals (absent in Australia) when the North and South American land masses collided.





Placental mammals are more diverse than marsupials, but over half of placental mammal species are either rodents or bats.

In addition to extended intrauterine gestation, placental mammals have nipples, larger brains, and teeth with greater functional differentiation into **incisors**, **canines**, **premolars**, and **molars**.

The current diversity of placental mammals can largely be characterized as a diversity of **limbs**, **teeth**, and **behavior**.

Unlike any marsupials, some mammals have:

- Evolved flight
- Become aquatic or marine
- Become huge
- Evolved social behaviors
- Specialized on abundant foods
  - like plankton and flying insects

Ten major clades (though there are a few smaller ones) :

Insectivora (moles, shrews, hedgehogs)

Chiroptera (bats)

Carnivora (dogs, cats, bears, skunks, raccoons, hyenas, seals, walrus)

Perissodactyla (horses, tapirs, rhinos)

Artiodactyla (pigs, hippos, camels, deer, giraffes, sheep, bison, cattle)

Xenarthra (anteaters, sloths, armadillos)

Cetacea (whales and dolphins)

Rodentia (squirrels, mice, rats, porcupines, beavers, capybaras, nutria)

Lagomorpha (rabbits, pikas, hares)

Primates (lemurs, monkeys, apes, humans)

Although you should learn these names, it is more important to know which placental mammals belong together within the same clades.

Primates evolved from **arboreal** (tree-living) mammals.
Many typical primate characters were probably adaptations for living, feeding, and moving in and between trees.


- Rotating shoulder joint
- Highly mobile and sensitive digits, including opposable thumb and big toe
- More complex eyes and 3-D vision
- Increased brain size


Six groups to consider:
Prosimians (lorises and lemurs)
Tarsiers
Old world monkeys
New world monkeys
Pongidae (large apes)
Hominidae (humans)

Six species of "great apes"

Orangutan
Eastern Gorilla
Western Gorilla
Bonobo
Chimpanzee
Human




Pongids cannot really be classified as a group separate from the hominids, since the closest relative of human beings is a pongid, the chimpanzee.


Human beings separated from chimpanzees about 5 million years ago.

The first hominids were several species of *Australopithecus* that lived on Earth at the same time as and probably interacted with one another.

Australopithecus afarensis was the smallest, but was probably the ancestor to the rest of the australopithecines, and to the genus *Homo*.

Homo sapiens are all believed to have come from a **single population from Africa**, after which they radiated into other parts of the world. However, it is not clear if all populations of *Homo* became "modern" humans on their own in parallel, or if a single African stock dispersed widely, gradually replacing other subspecies of *Homo* (such as *Homo neanderthalensis*, the Neanderthal.)

Geological history, continental drift and diversity

Historical forces have affected the diversification of life in different ways

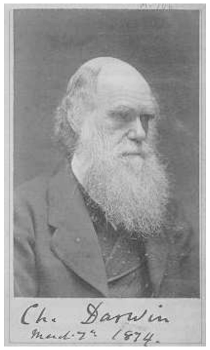
1) Changing climate and physical conditions
2) Rearrangements of the continents and ocean basins
3) Growth and erosion of mountains
4) Evolution (and immigration) of new predators, parasites and pathogens
5) Catastrophic collisions with asteroids

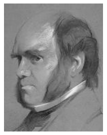
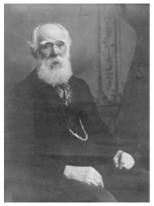
For these reasons, an exclusive focus on local environmental conditions will yield an incomplete understanding of diversity.

BIOGEOGRAPHY

attempts to explain why species and higher lineages are geographically distributed as they are, and why the diversity and species composition of the biota vary from one region to another.

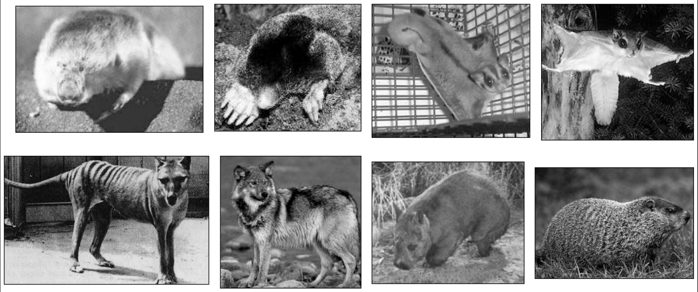
CHARLES R. DARWIN



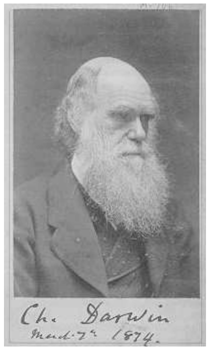
1. "Neither the similarity or dissimilarity of the inhabitants of various regions can be wholly accounted for by climatic and other physical conditions."

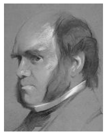
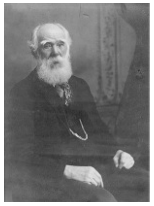
Ecological convergence of Australian mammals (marsupials) and North American mammals (placentals)



Similar habitats, ecology, and environmental conditions…
But evolutionarily unrelated animals!

CHARLES R. DARWIN



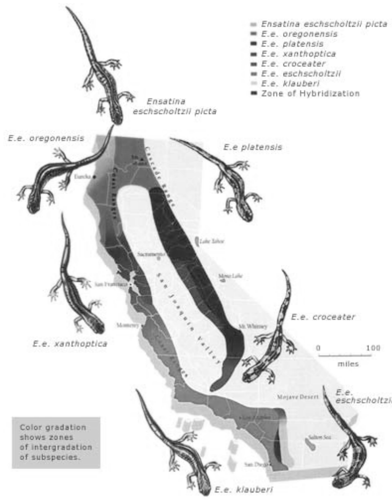



2. "Barriers of any kind…are related in a close and important manner to the differences between the productions [organisms] of various regions"

Ensatina sp. Salamanders of California

Found both west and east of the San Joaquin valley… but not in the valley

Salamanders can interbreed with those from populations to the north or the south... but salamanders at the two southern ends of the distribution "ring" cannot interbreed!



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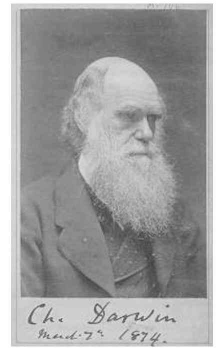
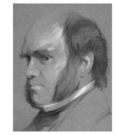
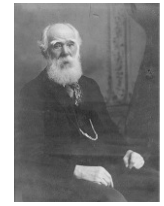


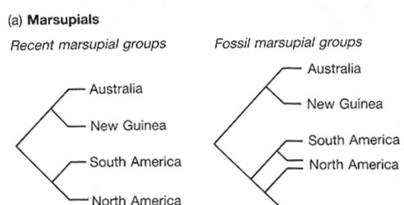




3. "Inhabitants of the same continent or the same sea are related, although the species themselves differ from place to place."

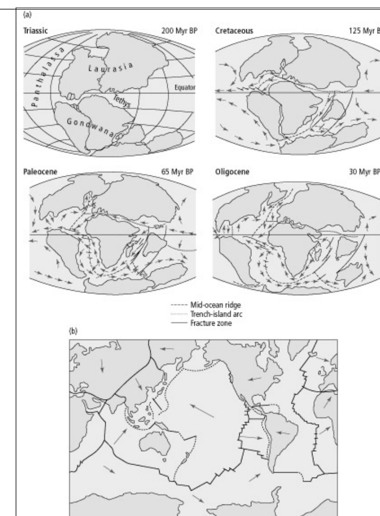
MARSUPIAL EXAMPLE

AREA CLADOGRAMS:

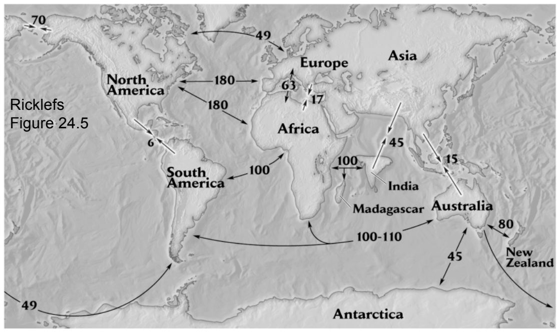


Geographic distributions of modern species are evidence of evolutionary descent from common, widespread ancestors

Gondwana and Laurasia: supercontinents that existed 200 MYA, and gradually broke apart through plate tectonics and continental drift



Geological history, continental drift and diversity

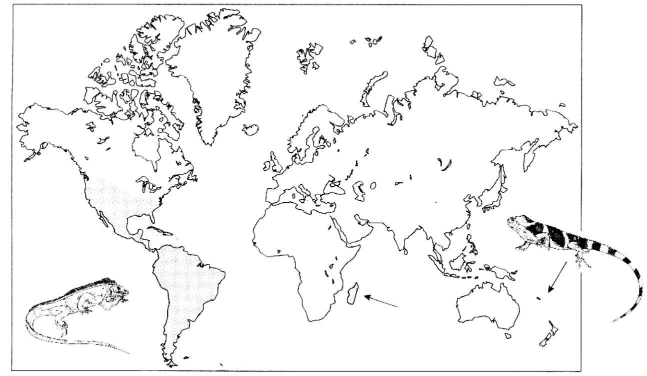


100 - 50 mya break up and southerly drift of Gondwana

70 mya Bering Sea land bridge

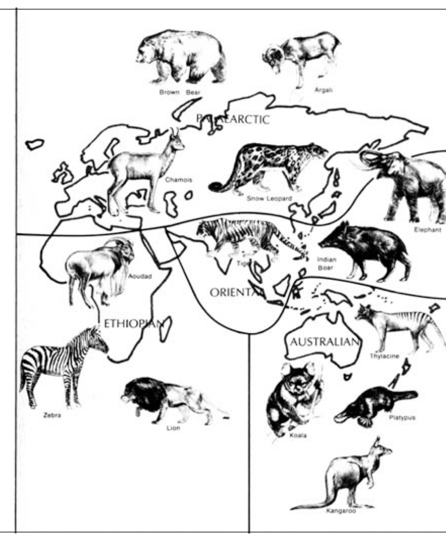
6 mya North America and South America meet

Descendants of Gondwana: Iguanid lizards

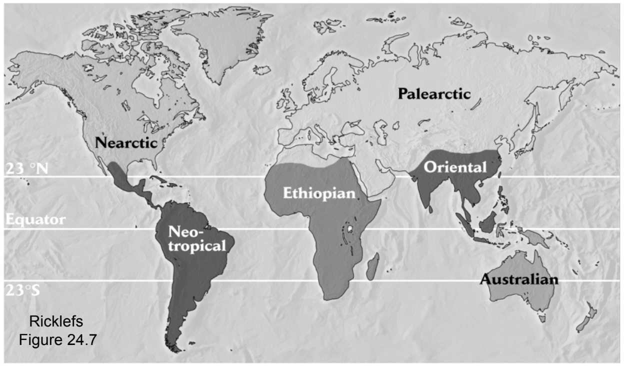


Alfred R. Wallace (remember him?)

… and other early biogeographers recognized that many types of organisms have similar geographic distributions, and that the species compositions of biota are more uniform within certain regions than between them.

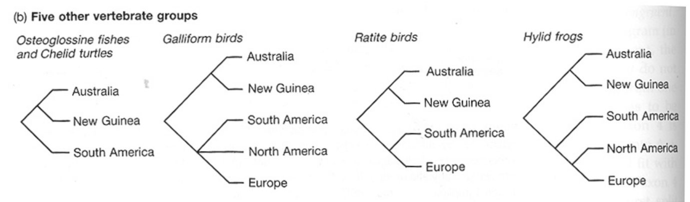


Geological history, continental drift and diversity

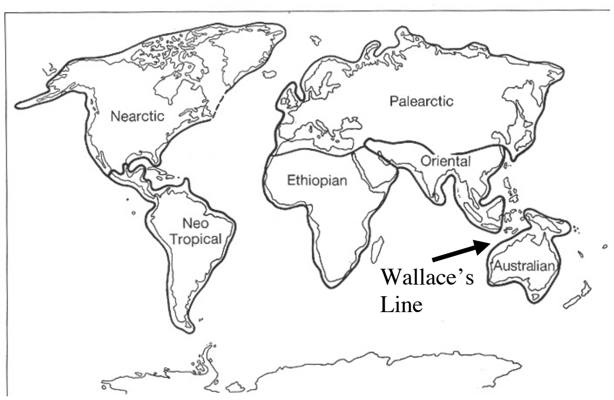


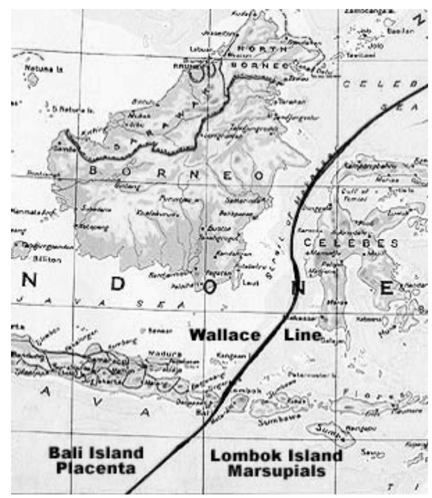
Biogeographic regions reflect the long-term isolation of large areas.

CONGRUENT BIOGEOGRAPHIES
(Comparative Phylogeography)



AN EXAMPLE OF BIOGEOGRAPHIC AREAS
Philip Sclater (1829-1913)





Wallace's Line:

Hypothetical division between Australasian and Southeast Asian faunas

Only 35km between Bali and Lombok islands!

Animals that "observe" the line: larger terrestrial mammals, amphibians, many birds, freshwater fish. Animals that don't: bats, flying foxes, "rafting" rats, shrews, and macaques

BIOREGIONS AT VARIOUS SPATIAL SCALES

Two types of history that explain geographic distributions of organisms

- Vicariance

- Dispersal

DISPERSAL VS. VICARIANCE HYPOTHESESES

1. Dispersal Hypothesis: Taxon originated in one area and dispersed to the other

"I go new places"

2. Vicariance Hypothesis: Areas were formerly contiguous, and were occupied by the ancestor. Species differentiated after barrier arose.

"I stay where I am"

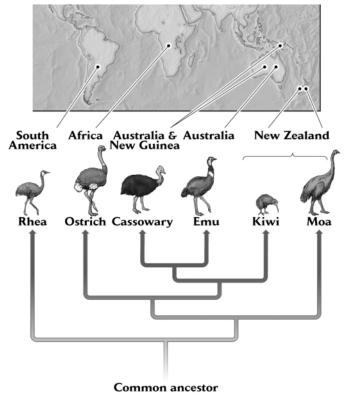
Disjunct Distribution

History of connections between the continents endures in the distributions of animals and plants.

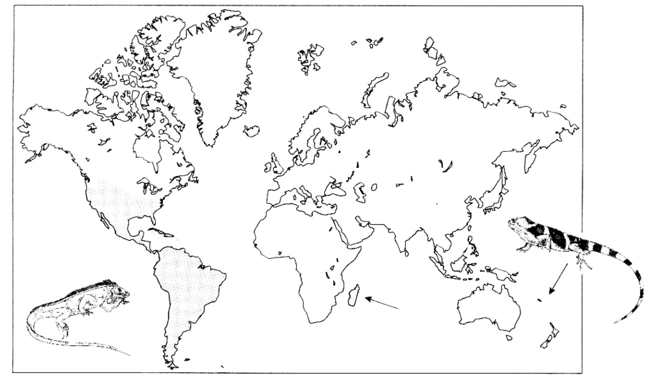
Ratites are descended from a common ancestor that inhabited Gondwanaland before its breakup.

All extant ratites are flightless.

This is an example of **vicariance.**

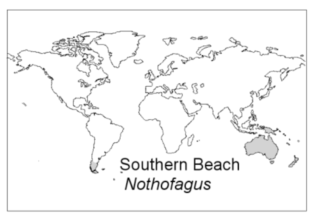


Descendants of Gondwana: Iguanid lizards



Geological history, continental drift and diversity

Like the ratites, southern Beech (*Nothofagus*), has a highly disjunct and southerly distribution best explained by the relatively recent breakup of Gondwana.



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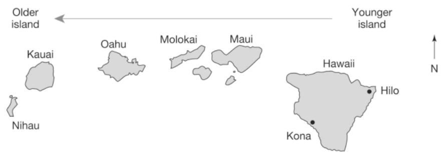
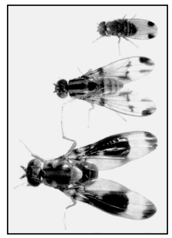
Distributions of Hawaiian *Drosophila*

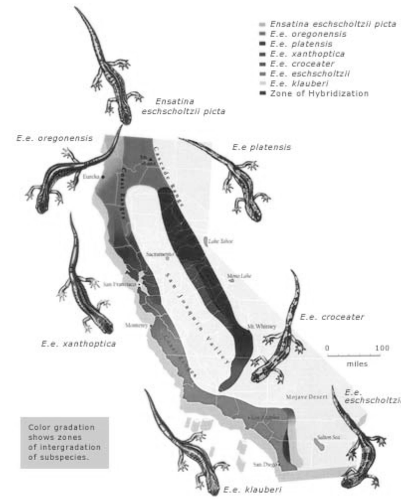




Ensatina sp. Salamanders of California

The salamanders originated in the northern U.S., and gradually dispersed through California to the South

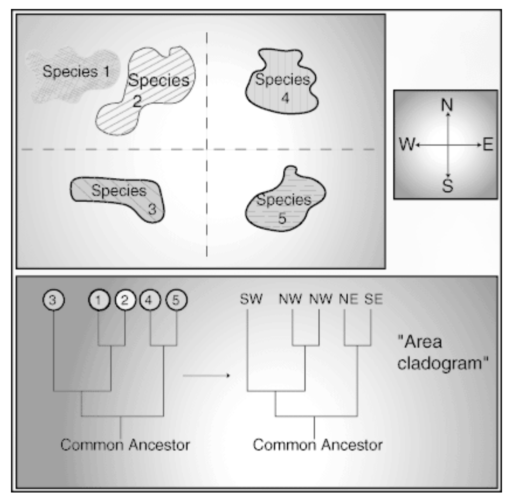
Populations spread along the sides of the San Joaquin Valley, but not in the valley

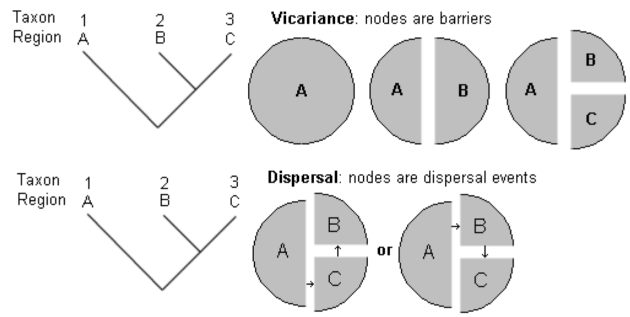


To test hypotheses about biogeography, we ask:

How does the **phylogenetic history** of our organisms of interest, relate to the **geographical history** of their distributions?

For this type of question, we can use **area cladograms.**



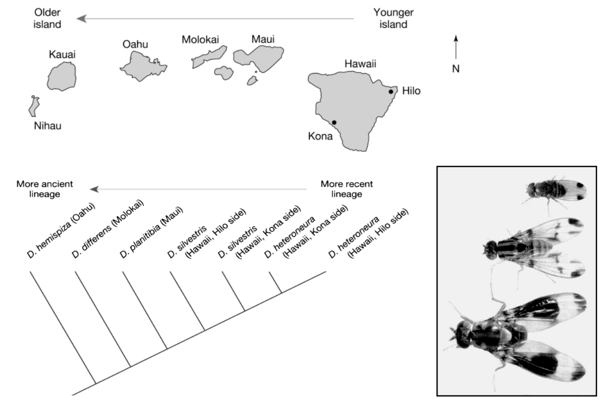


The area cladogram uses phylogenetic relationships to trace geographical changes - either dispersal events or barriers to dispersal.

The **vicariance hypothesis** is that the first barrier resulted in the trait that differentiated B & C from A, and the second barrier resulted in the trait that differentiated B from C.

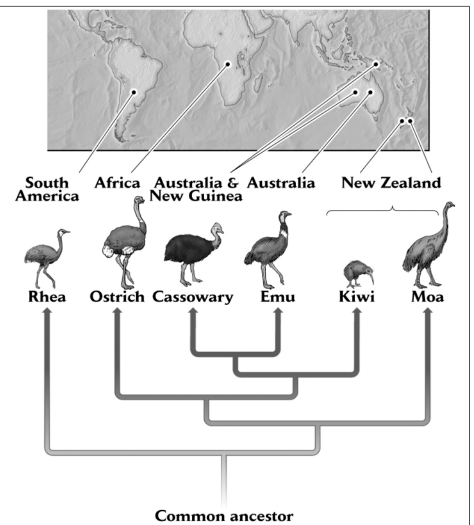
The **dispersal hypothesis** is that traits arose after each dispersal. However, the sequence of dispersals is not shown by the cladogram.

Hawaiian *Drosophila:* an example of dispersal



Ratite birds:

An example of vicariance



ECOLOGY (ESSENTIAL)

A species cannot survive outside of its physiological tolerance range; its biogeography cannot contradict its ecology.

ECOLOGY (ESSENTIAL)

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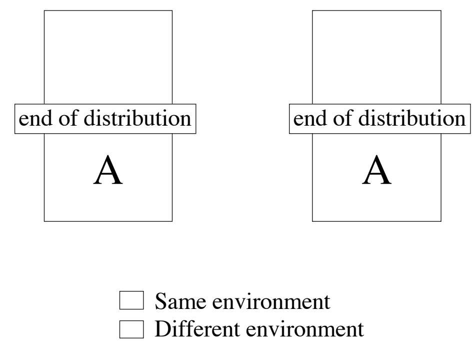
Are Ecological and Historical Factors Alternatives?

DETERMINING IF ECOLOGY OR HISTORY IS MORE IMPORTANT



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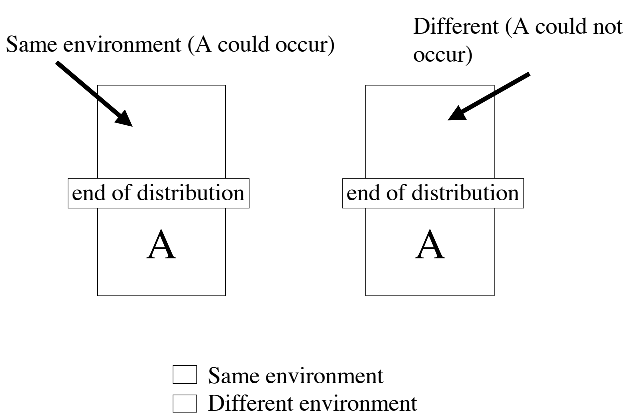

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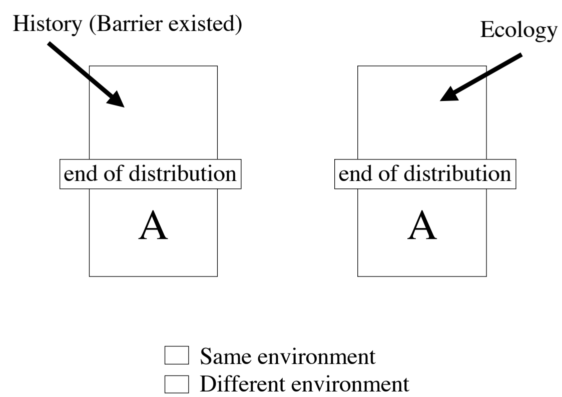


Island biogeography

Patterns of island diversity have long attracted the attention of ecologists.

Islands are bounded habitats.

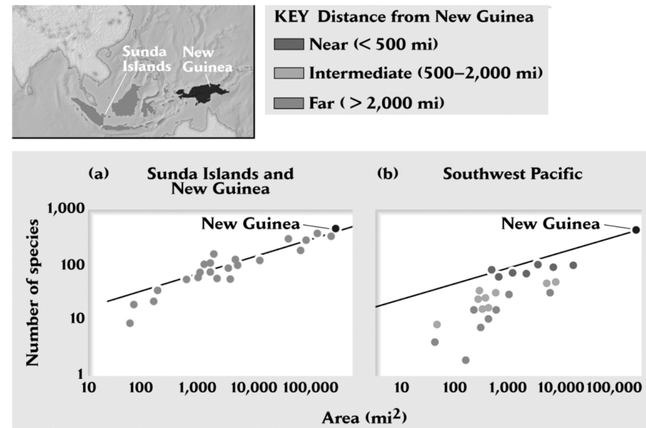
In the 1960s, Robert MacArthur and Edward O. Wilson developed the **equilibrium theory of island biogeography.**

Their theory proposed the following:

(1) The number of species on an island balances regional processes governing **immigration** against local process governing **extinction.**

(2) Diversity results in an **equilibrium** between **extinction** and **colonization.**

Island biogeography



Both area and distance affect bird diversity.

MacArthur and Wilson 1967

Theory of Island Biogeography

“Why do islands have fewer species than same area on continent?”

Function of SIZE of island and DISTANCE from mainland

Small islands have higher extinction rates.
Farther islands have lower probability of immigration.

Island biogeography

The equilibrium theory of island biogeography

Consider an island (or any other isolated habitat)

***Addition of species results from immigration*:**

The rate of arrival of new species is a declining function of the number of species already on the island

Removal of species results from extinction:

The rate of extinction is an increasing function of the number of species already on the island

Island biogeography

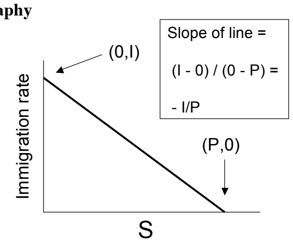
The equilibrium theory of island biogeography

Immigration rate = I - (I/P)S

I = maximum immigration rate

P = mainland species pool

S = number of species on island



The maximum immigration rate occurs when S = 0

Immigration rate decreases with increasing S because fewer new species from P remain as potential colonists.

Island biogeography

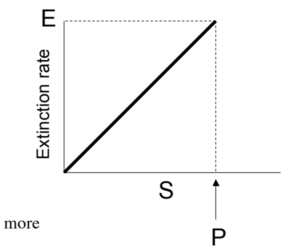
The equilibrium theory of island biogeography

Extinction rate = (E/P)S

E = maximum extinction rate

P = mainland species pool

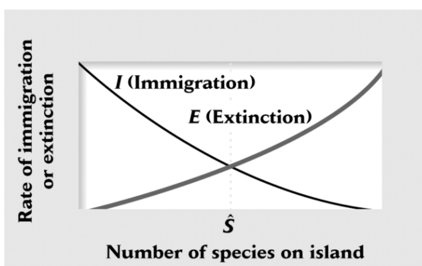
S = number of species on island



The more species present on an island, the more that can disappear.

The maximum extinction rate occurs when S = P

Island biogeography



Species differ in their dispersal capabilities and their susceptibility to extinction.

I curve: species that dispersal well arrive soon, poor dispersers show up later.

E curve: competition will increase the extinction rate with increasing S.

(Basic predictions of model remain the same whether linear or non-linear rate curves are used)

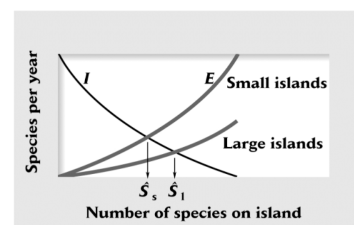
Island biogeography

Extinction curves should be higher for small islands than for large ones:

smaller islands generally have smaller populations

small population size increases the risk of extinction

Immigration rates may also be lower on small islands, relative to those on large islands, because smaller islands are less of a target.



Island biogeography

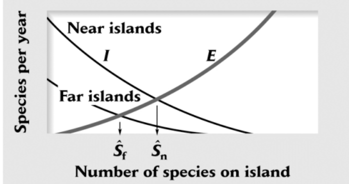
Immigration curves should be lower for distant islands than for nearer ones:

More distant islands are less likely to be colonized: thus more distant islands should have fewer species.

Island isolation may also affect rates of extinction.

Populations of species may be replenished by immigrants more often when islands are close to mainland sources than when they are far away.

Ricklefs Figure 23.16



Species-area relationships: different types of islands

Mammals on mountaintops in the Great Basin of Nevada and Utah also provide an example of a non-equilibrium assemblage

Continuous conifer forests occurred throughout the Great Basin at the end of the last Ice Age

As the climate became warmer and drier over the past 20,000 years conifers (and the other organisms that are restricted to this habitat) became isolated on mountaintops throughout the Great Basin

Mountaintop conifer forest can thus be considered a series of landbridge "sky" islands.

Mammals restricted to conifer forest exhibit a poor ability to cross desert lowlands.

Island biogeography

Experimental tests of the equilibrium theory of island biogeography

Dan Simberloff, EO Wilson's graduate student, tested certain predictions of the MacArthur-Wilson model.

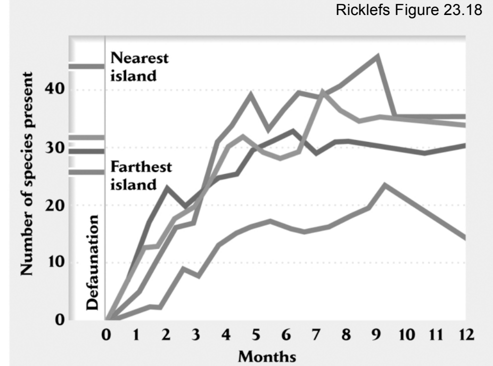
Simberloff and Wilson de-faunated small clumps of mangroves in Florida bay that differed in their distance from the mainland.

Prediction 1: insect diversity would attain pre-removal levels (equilibrium)

Prediction 2: close islands would be colonized more quickly compared to more distant islands

Island biogeography

Ricklefs Figure 23.18



Colonization of mangrove islands by insects in Florida Bay following fumigation.