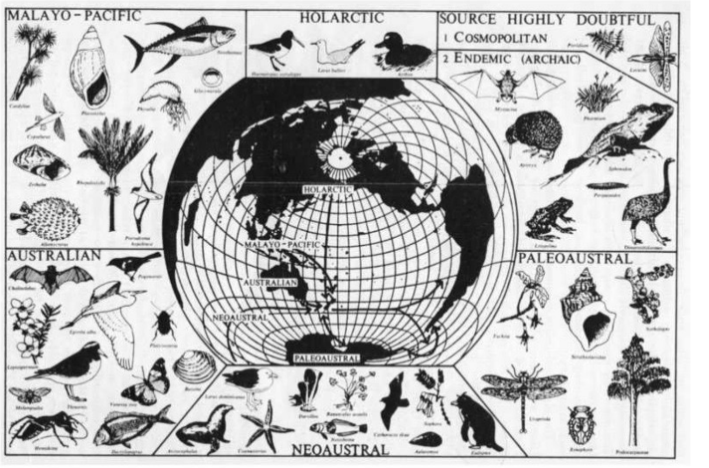


Biogeography

Autumn 2021

Kristiina Tambets, Institute of Genomics, EBC
kristiina.tambets@ut.ee

Framework of the lecture

Biogeography, ecogeography and phylogeography;

The history of biogeography;

Biogeographical regions;

Distribution types and models of the spread of species;
Factors behind the present spread of species:
- ecology and climate;
- plate tectonics;

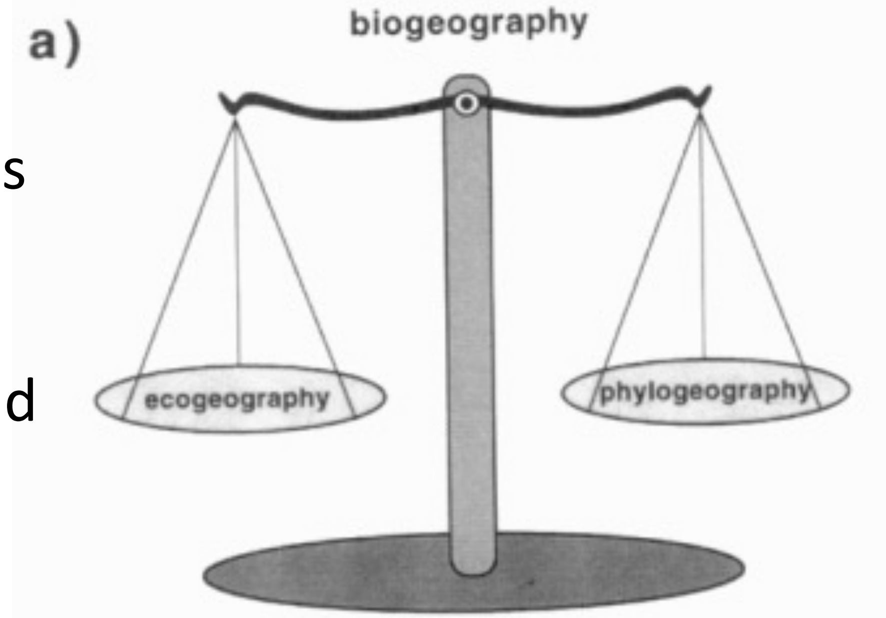
Migrations of species in time and space - reconstructions of demographic history of species based on their genetic variation

Biogeography

Biogeography – science that seeks to explain the distributions of species (and higher taxa) and ecosystems and the factors that have shaped the patterns of these distributions in time and space

Ecogeography –concentrates on the *present time* and studies the influences of abiotic (humidity, soil, light regime etc.) and biotic environment (other species) on the structure, dynamics and distribution of a population.

Stresses the importance of natural selection (ecogeographical rules and gradients of characters).

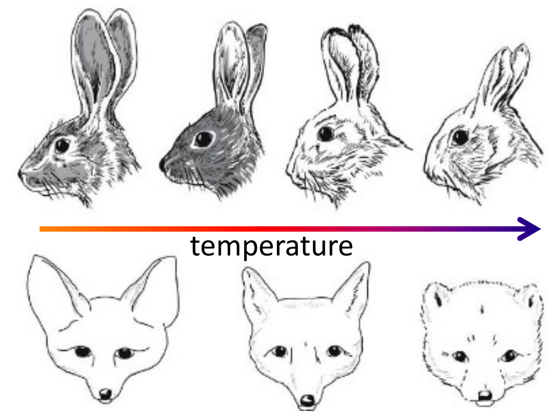


Work on different time depth and geographic magnitude

Biogeography

<u>Some classical ecogeographical rules:</u>

<u>Allen`s rules</u>: homeotermic (warm-blooded) animals adapted to cold climates have relatively short limbs (and ears and tails) compared to those who live in warm climate (*to give away less energy*);



<u>Bergmann`s rules</u>: in a broadly distributed species of homeothermic animals the body sizes are larger in colder environments and smaller in warmer regions *(to give away less energy – latitude matters)*;

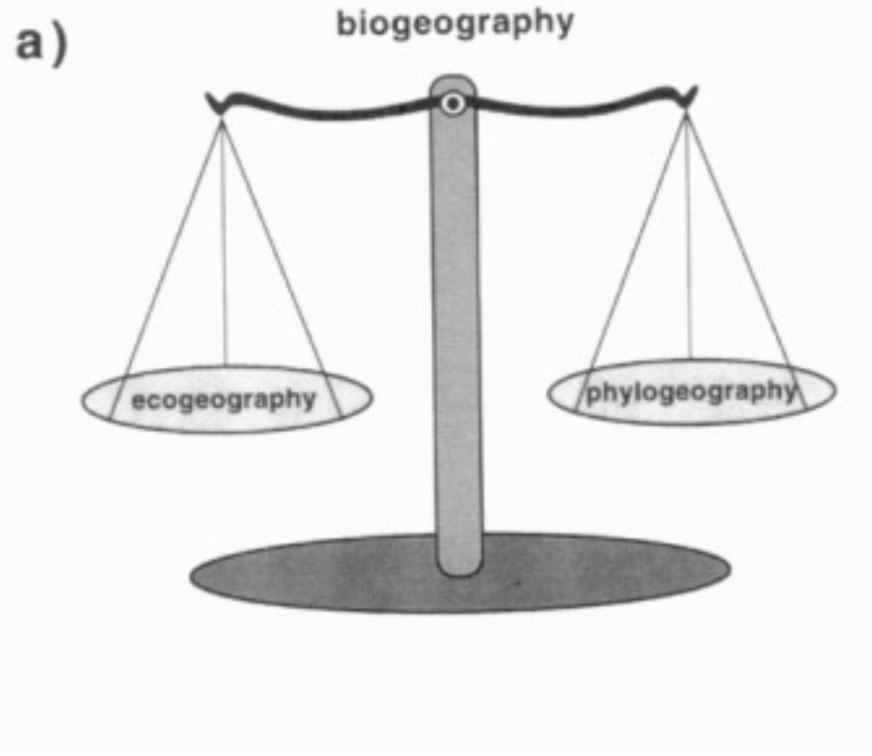
<u>Gloger`s rule</u>: in warm and humid climate the homeotermic animals are usually darker (more pigment) than their relatives in cold and dry climate (*helps to hunt or gives defence against predators, associated also with the amount of UV light*)

Biogeography

Biogeography – study of the distributions of species and ecosystems and the factors that have shaped the patterns of these distributions in time and space

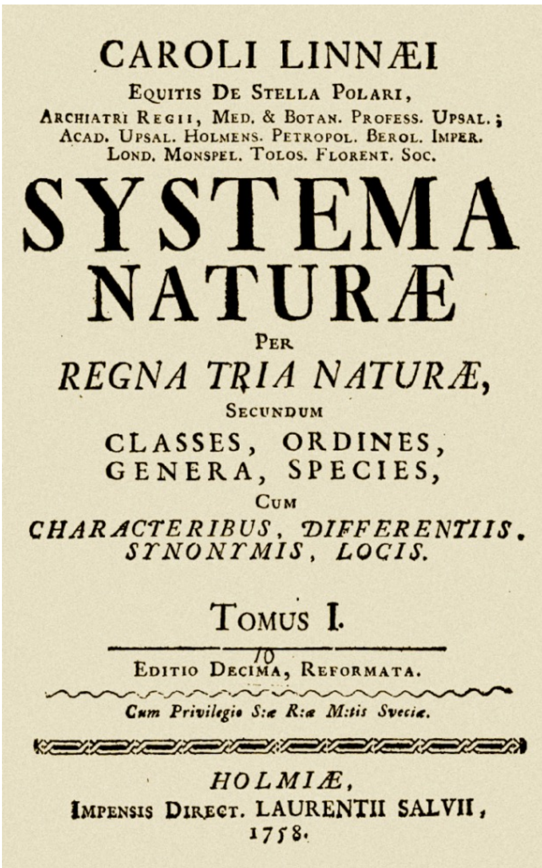
Phylogeography – deals with processesses in *geological* and *historical* time scale (climatic changes, continental drift *etc*.) and studies the **relationships** between **demographic history** and **phylogeny**.

Brings to biogeography a **temporal dimension**.



Biogeography - history

The basis of biogeography is the classification of living world – into species or higher taxons



CAROLI LINNÆI
EQUITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.;
ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

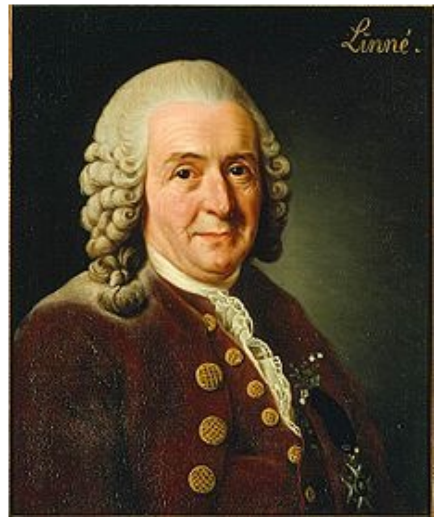
SYSTEMA NATURÆ
PER
REGNA TRIA NATURÆ,
SECUNDUM
CLASSES, ORDINES, GENERA, SPECIES,
CUM
CHARACTERIBUS, DIFFERENTIIS. SYNONYMIS, LOCIS.

TOMUS I.

EDITIO DECIMA, REFORMATA.

Cum Privilegio S:æ R:æ M:tis Sveciæ.

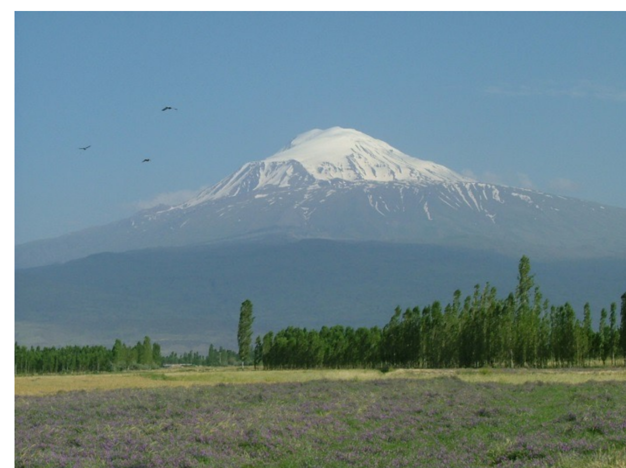
HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1758.



Carl Linne (1707-1778) - **species do not change!**

According to his theory, postdiluvian life comes *ca* 6000 ya from the Mountain of Ararat – this was the place where he thought the Noah`s Ark landed

Binary nomenclature
ca 4400 animal
(*Homo sapiens*)
and 7700 plant species



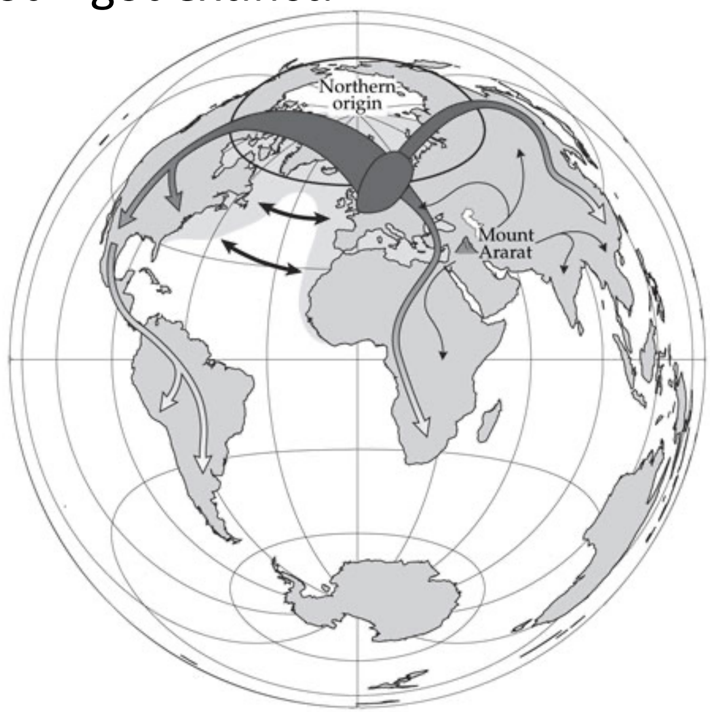
Linnaea borealis
twinflower

Biogeography - history

George-Louis de Buffon
(1707-1788)

According to his comparative studies of modern species and fossils of northern Eurasia he concluded that the postdiluvial life on Earth started to spread from Northern Europe, which, he believed, was warm at that time. When the climate got colder, the species had to adapt, those who did not – got extinct.

<u>Buffon`s law</u>: environmentally similar but isolated regions have distinct assemblages of mammals and birds (becomes principle of biogeography)



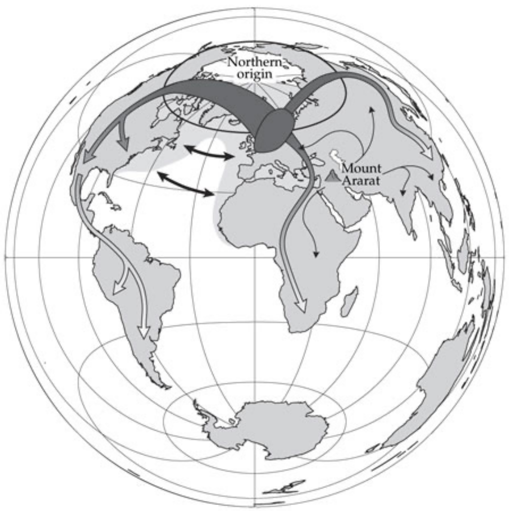
BIOGEOGRAPHY, Third Edition, Figure 2.1 © 2006 Sinauer Associates, Inc.

<u>Importance:</u>
- changing climate;
- adaptations - **species can change if environment changes!**

Until 20. century the main model to explain biological diversity and the distribution of species was the **centre-of-origin and dispersal model**

Biogeography - history

I. **centre-of-origin and dispersal model - dispersionists**



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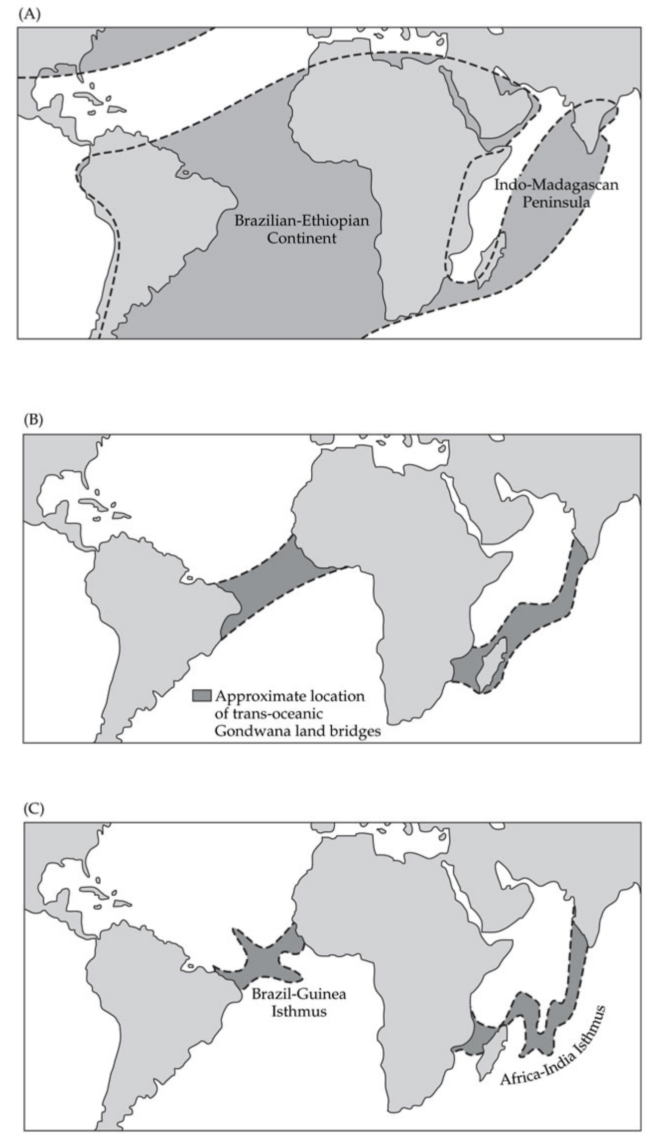
There were also other theories:

II. **extensionists** (Ch. Lyell 1797-1875) – behind the present spread of the terrestrial species are **land-bridges** that have disappeared (today this is explained by the theory of continental drift)



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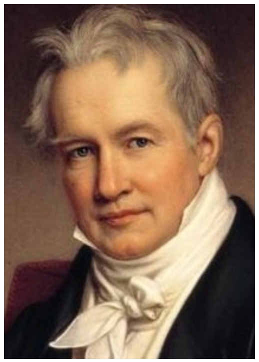
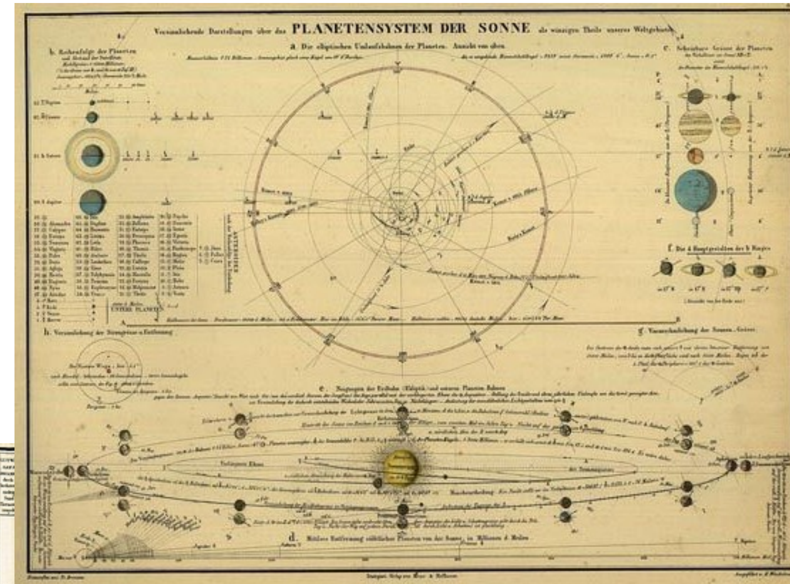
Biogeography - history

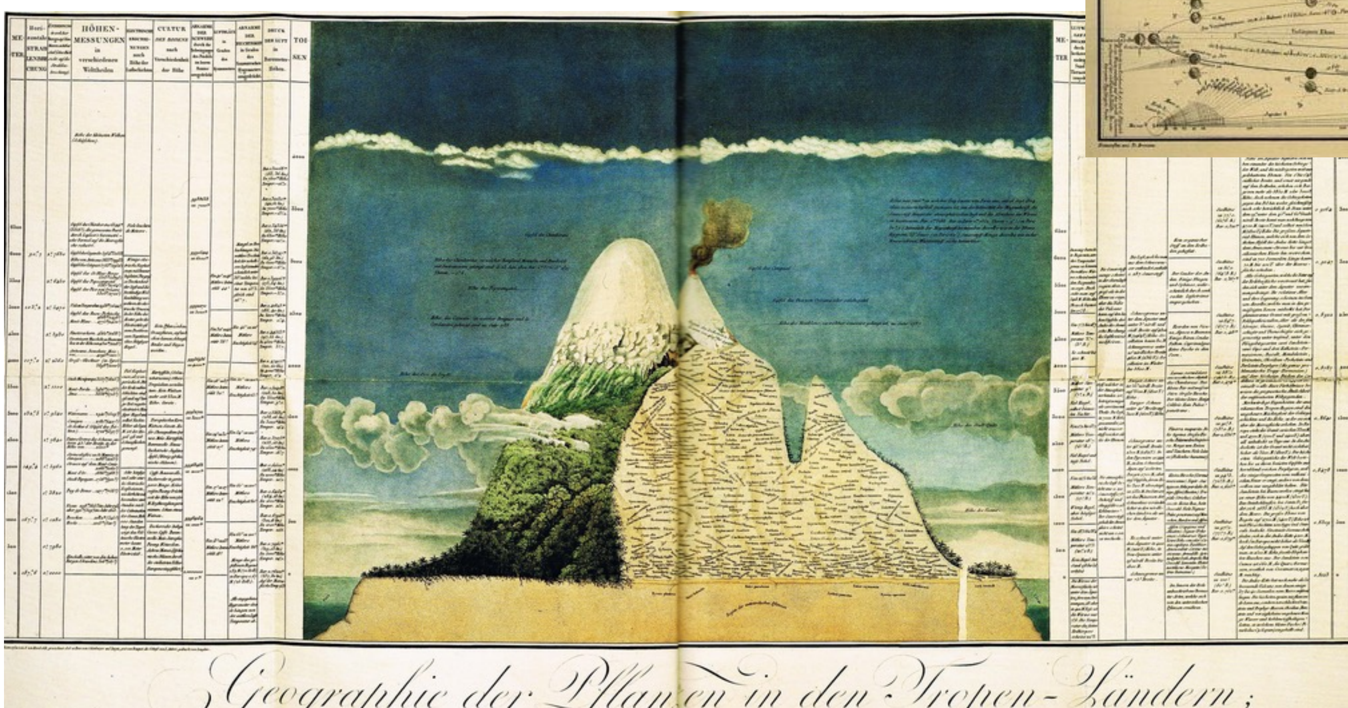
Alexander v. Humboldt (1769-1859) – German natural scientist, founder of physical geography, one of the first scientists who believed that the continents around the Atlantic Ocean were once connected

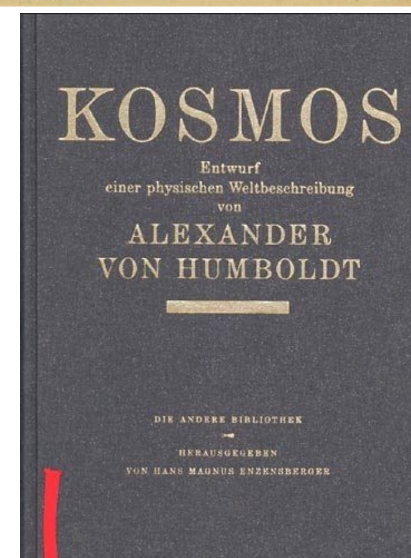


1827 Honorary doctor of UT

1845 – Kosmos (*Space*)







Biogeography - history

Philip Lutley Sclater (1829-1913) – defined **6 biogeographic regions** (1864) according to the differences in composition of bird species in different regions. For plants, the same was done by **Adolf Engler** (1844-1930)

Biogeographical regions – large areas with specific fauna and flora

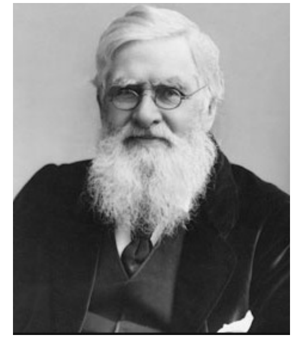
Historical regions are:

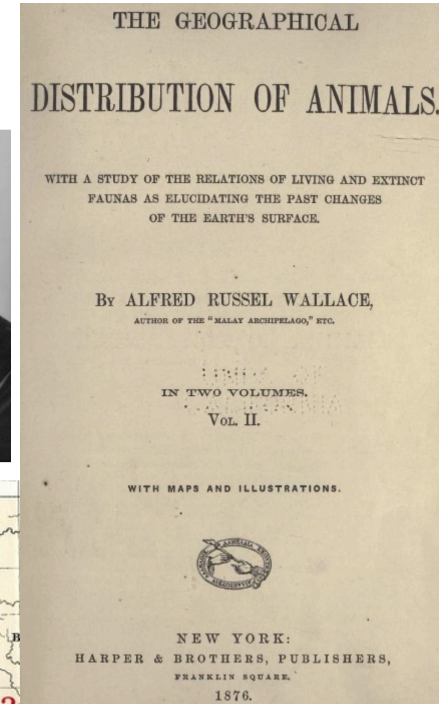
- Nearctic;
- Neotropic;
- Palearctic;
- Afrotropic;
- Indo-Malai;
- Australasia

Biogeography - history

Alfred R. Wallace (1823-1913) – developed the theory of biogeographical regions over many species, emphasized the role of environment in shaping the diversity

1876 map – backbone of biogeography




THE GEOGRAPHICAL

DISTRIBUTION OF ANIMALS.

WITH A STUDY OF THE RELATIONS OF LIVING AND EXTINCT FAUNAS AS ELUCIDATING THE PAST CHANGES OF THE EARTH'S SURFACE.

By ALFRED RUSSEL WALLACE,

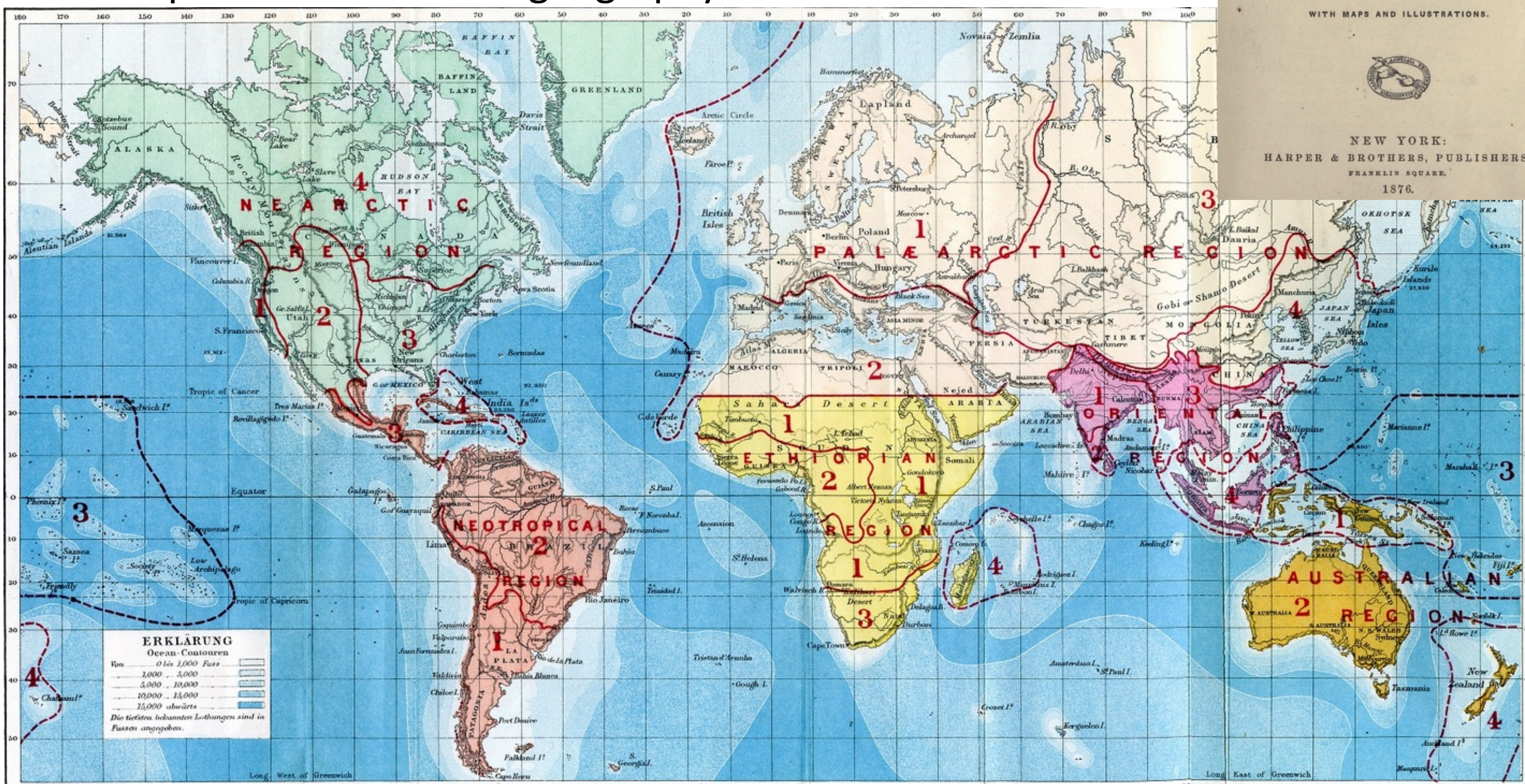
AUTHOR OF THE "MALAY ARCHIPELAGO," ETC.

IN TWO VOLUMES.

VOL. II.

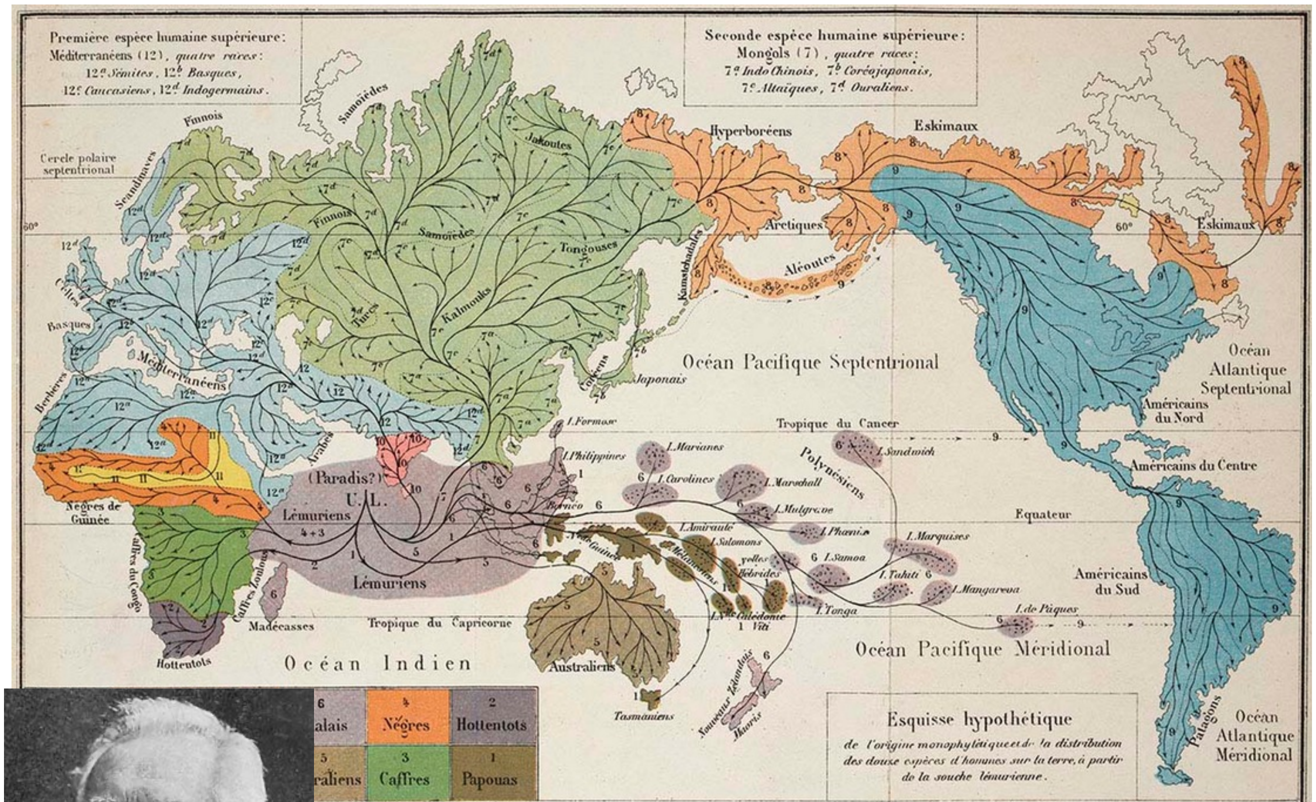
WITH MAPS AND ILLUSTRATIONS.

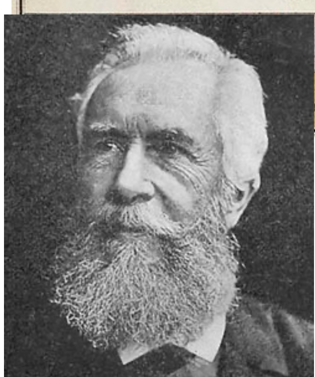
NEW YORK:
HARPER & BROTHERS, PUBLISHERS,
FRANKLIN SQUARE.
1876.



Biogeography - history

Sclater (1864) - Lemuria – lost continent in Indian Ocean





Ernst Haeckel
(1834-1919)

The **static** biogeographical regions of Sclater and Wallace started to be **dynamic** due to Haeckel

Lemuria hypothesis tried to explain the distribution of African and South-East Asian little arboreal primates and Madagascarian Lemurs (*today this can be explained with the drift of continents*).

E. Haeckel used Lemuria in his map of animal migrations. He considered Lemuria as a cradle of humans and believed that lemurs are their ancestors

Biogeography - history

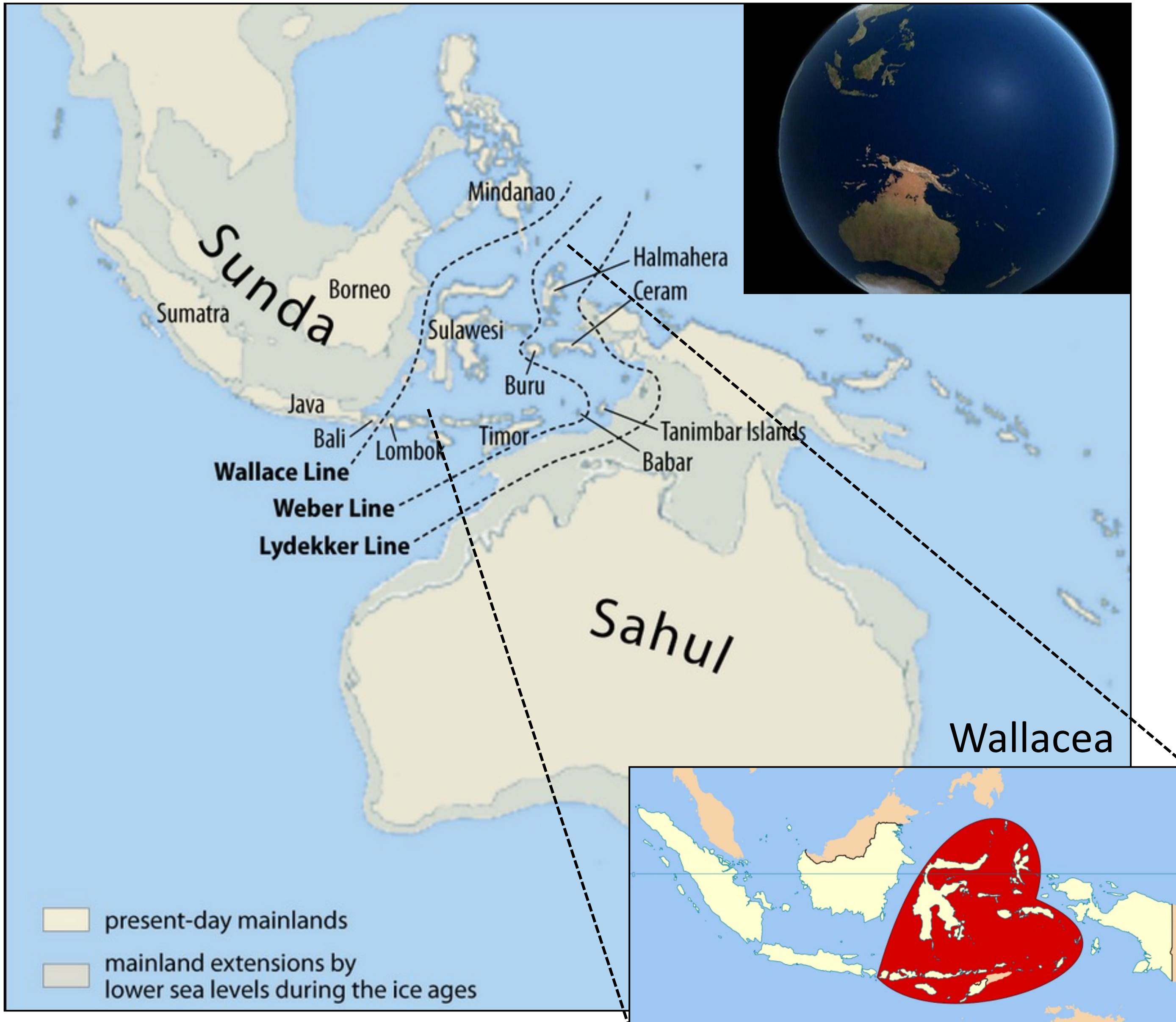
Wallacea -

Biogeographic region of Indonesian islands.

West border is a **Wallace line** along the Makassar strait, east border is **Lydekker line**

Weber line - middle zone, where Australian and Asian fauna and flora is 50/50.

Australia and Antarctic 40 – 35 Mya



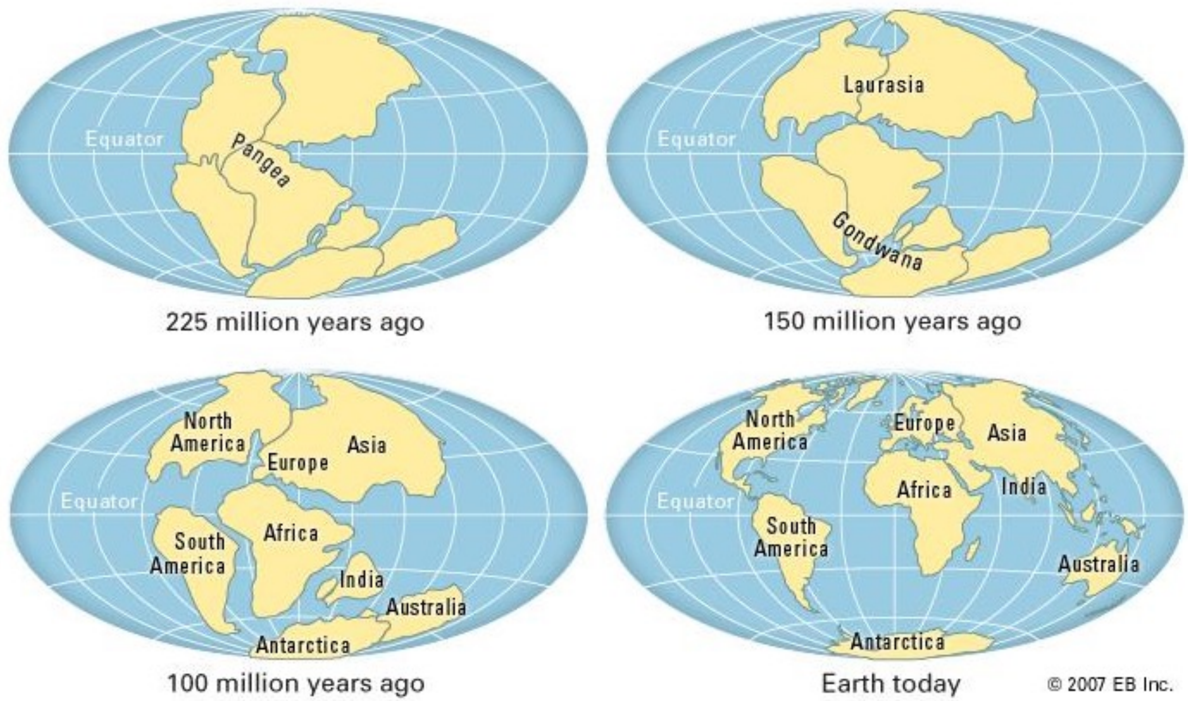
Wallacea

Biogeography - history

Continental drift – some of the patterns of present distribution of species was hard to explain – very long distances between close species

1912 - **Alfred Wegener** (1880-1930) *"The Origin of Continents and Oceans"*

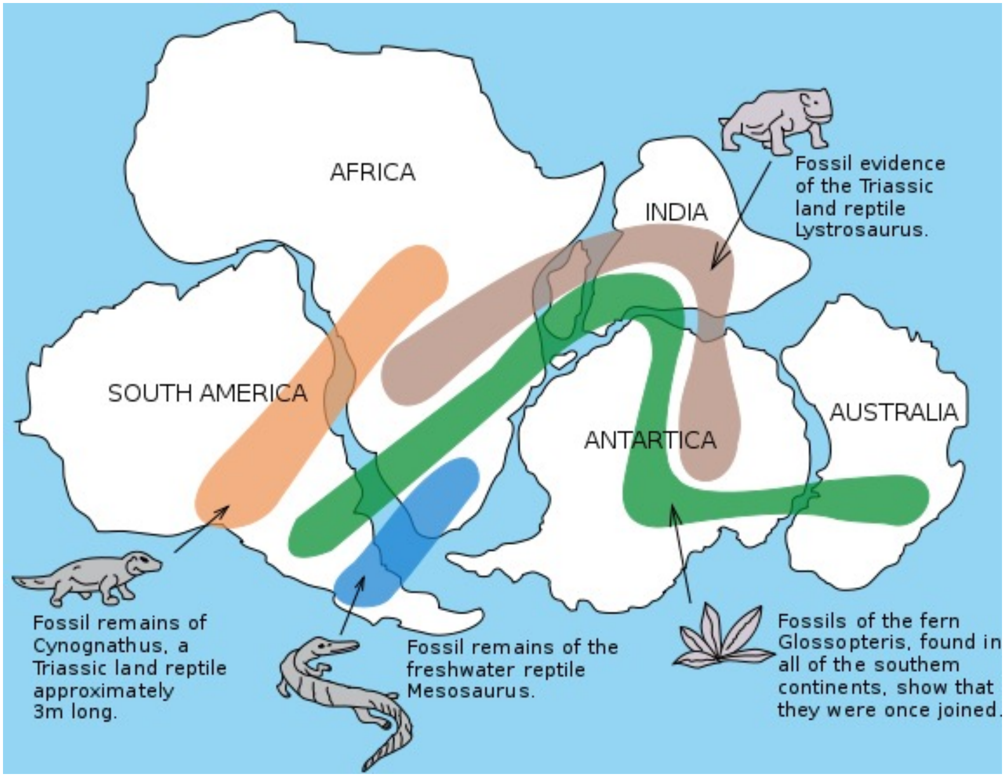
Similar fossils in distant continents refer to the contacts between continents in a distant past.
Ancient continent **Pangea** – "all lands"



Abraham Ortelius (1596)

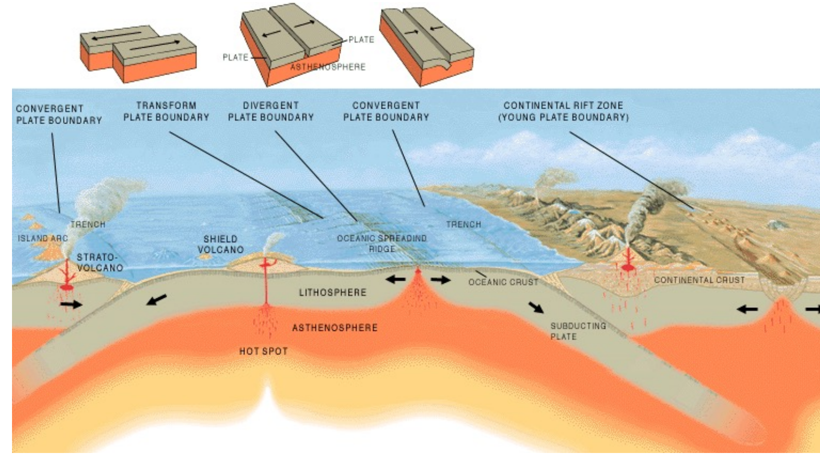
Eduard Suess (1885) – **Gondwana –** similar fossils of ferns in different continents

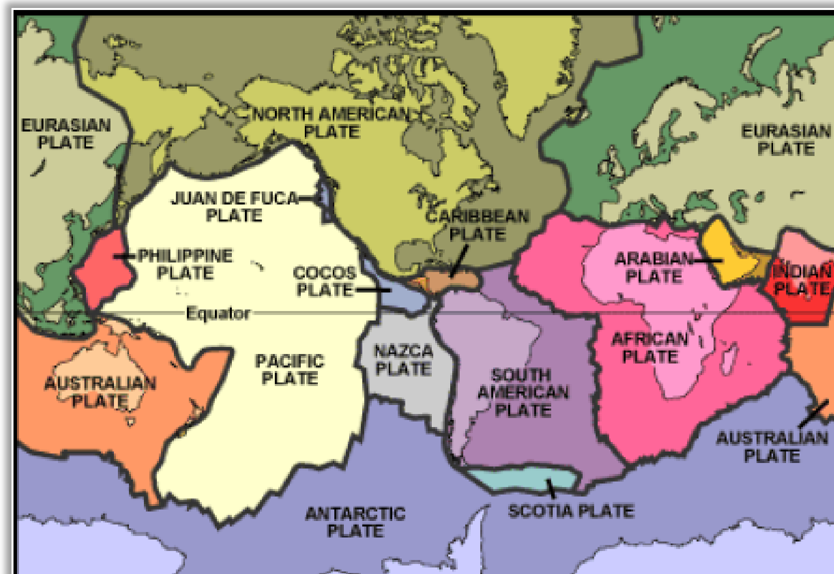
Biogeography - history



Fossils of Gondwana

Theory of continental drift and plate tectonics gave an explanation how to understand the global patterns of biogeographical distribution of species





The Earth's crust has been found to be composed of several distinct plates.

Plate tectonics

http://www.crystalinks.com/platetectonics.html

Present-day view on Wallace's zoogeographical regions

An Update of Wallace's Zoogeographic Regions of the World

4 JANUARY 2013 VOL 339 SCIENCE

Ben G. Holt,[1*] Jean-Philippe Lessard,[1*†] Michael K. Borregaard,[1] Susanne A. Fritz,[1,2] Miguel B. Araújo,[1,3,4] Dimitar Dimitrov,[5] Pierre-Henri Fabre,[5] Catherine H. Graham,[6] Gary R. Graves,[1,7] Knud A. Jønsson,[5] David Nogués-Bravo,[1] Zhiheng Wang,[1] Robert J. Whittaker,[1,8] Jon Fjeldså,[5] Carsten Rahbek[1]

Modern attempts to produce biogeographic maps focus on the distribution of species, and the maps are typically drawn without phylogenetic considerations. Here, we generate a global map of zoogeographic regions by combining data on the distributions and phylogenetic relationships of 21,037 species of amphibians, birds, and mammals. We identify 20 distinct zoogeographic regions, which are grouped into 11 larger realms. We document the lack of support for several regions previously defined based on distributional data and show that spatial turnover in the phylogenetic composition of vertebrate assemblages is higher in the Southern than in the Northern Hemisphere. We further show that the integration of phylogenetic information provides valuable insight on historical relationships among regions, permitting the identification of evolutionarily unique regions of the world.

Distribution and phylogenetic data have been used together

Present-day view on Wallace’s zoogeographical regions

4 JANUARY 2013 VOL 339 **SCIENCE**

Fig. 1. Map of the terrestrial zoogeographic realms and regions of the world. Zoogeographic realms and regions are the product of analytical clustering of phylogenetic turnover of assemblages of species, including 21,037 species of amphibians, nonpelagic birds, and nonmarine mammals worldwide. Dashed lines delineate the 20 zoogeographic regions identified in this study. Thick lines group these regions into 11 broad-scale realms, which are named. Color differences depict the amount of phylogenetic turnover among realms. (For more details on relationships among realms, see the dendrogram and NMDS plot in fig. S1.) Dotted regions have no species records, and Antarctica is not included in the analyses.

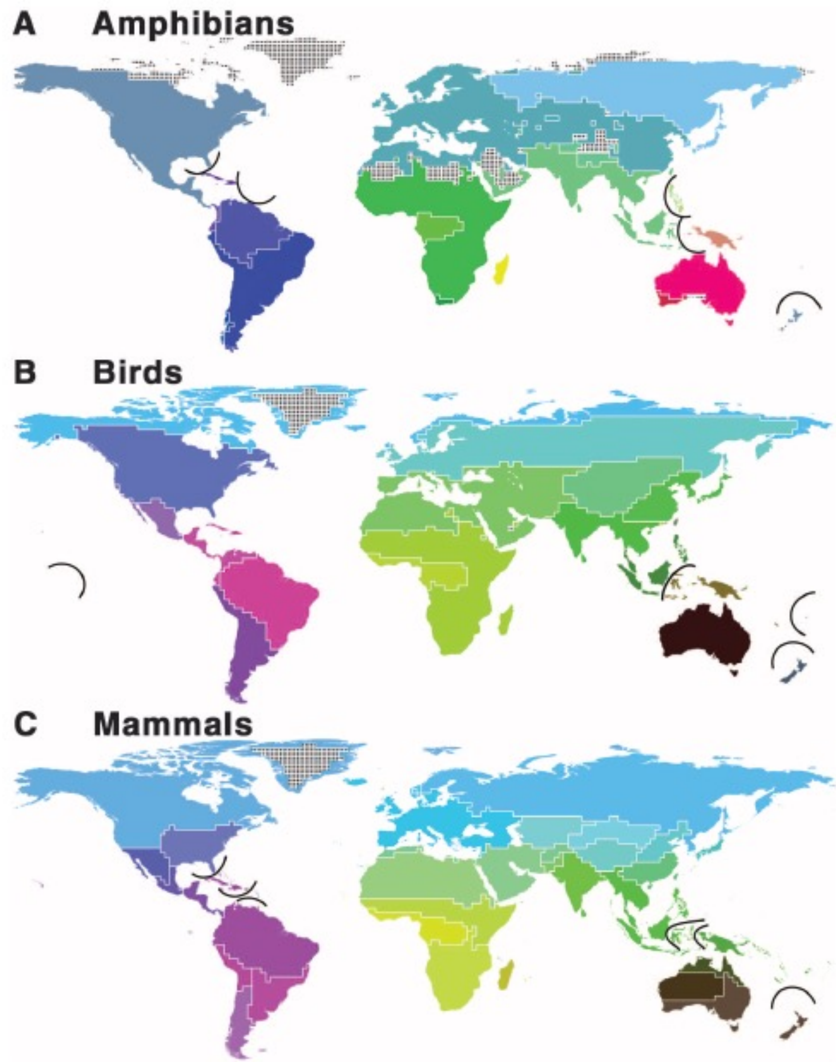
Instead of Wallace`s **6 regions** today **11 realms** are used.
South America has been separated from Panama, Saharo-Arabia and Sino-Japanese from Palearctic, Madagascar from Africa, Oceania from Australia.

<u>Conclusion:</u> according to this model, the line of Wallace should go from east side of Sulawesi island, like it was shown by Weber *ca* a century ago.

Present-day view on Wallace’s zoogeographical regions

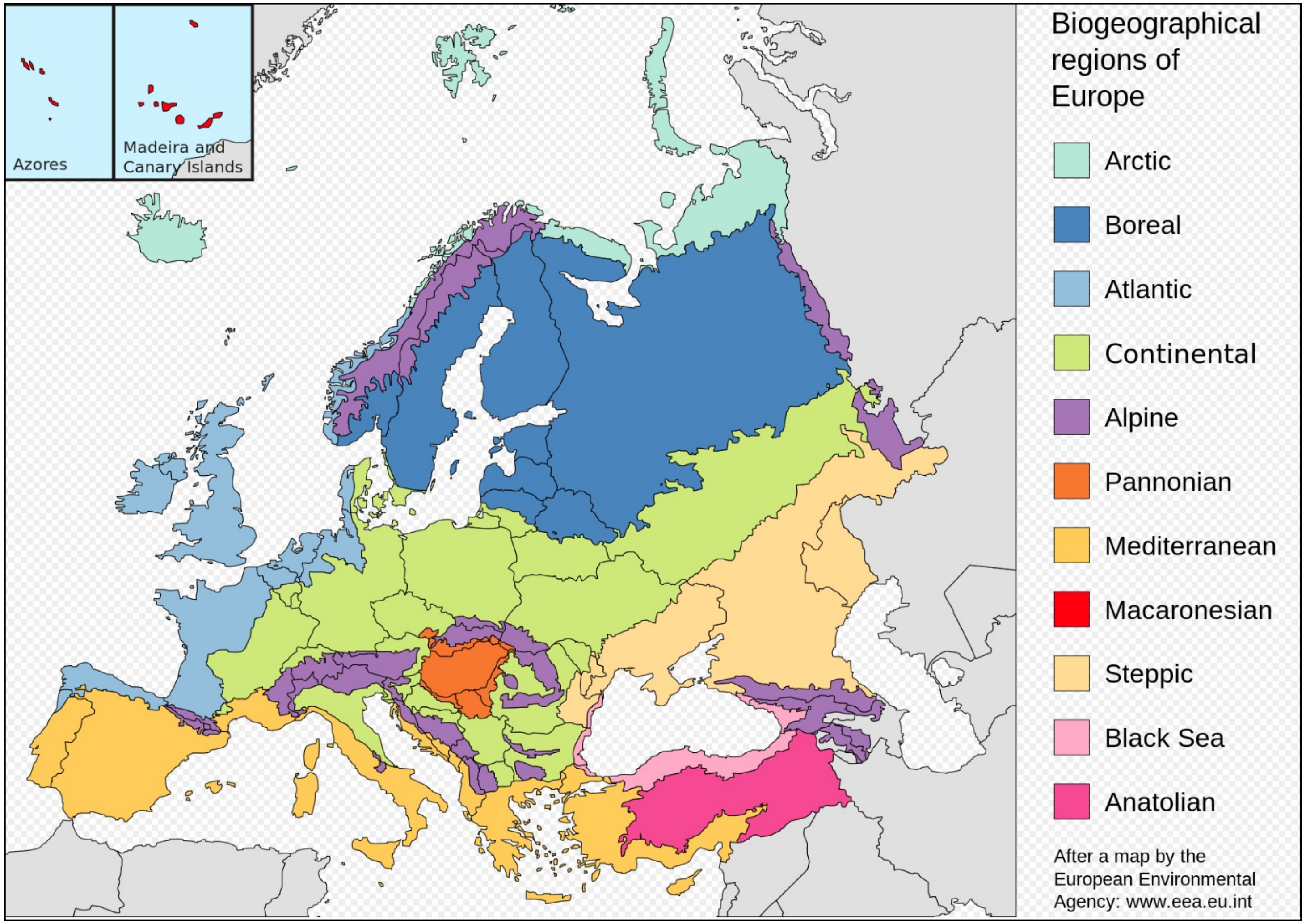
4 JANUARY 2013 VOL 339 SCIENCE

Fig. 3. Maps of terrestrial zoogeographic regions of the world based on data for (**A**) amphibians (6110 species), (**B**) birds (10,074 species), and (**C**) nonmarine mammals (4853 species). Color differences depict the relative amount of phylogenetic turnover among regions within each taxonomic clade. (For more details on relationships among regions, see the dendrogram and NMDS plots in fig. S4, A to C.) Dotted regions have no species records, and Antarctica is not included in the analyses.



http://macroecology.ku.dk/resources/wallace

Local divisions of biogeographical regions - Europe



nature ecology & evolution

ARTICLES

PUBLISHED: 6 MARCH 2017 | VOLUME: 1 | ARTICLE NUMBER: 0089

Global determinants of zoogeographical boundaries

Gentile Francesco Ficetola[1,2]*, Florent Mazel[1,3] and Wilfried Thuiller[1]

The distribution of living organisms on Earth is spatially structured. Early biogeographers identified the existence of multiple zoogeographical regions, characterized by faunas with homogeneous composition that are separated by biogeographical boundaries. Yet, no study has deciphered the factors shaping the distributions of terrestrial biogeographical boundaries at the global scale. Here, using spatial regression analyses, we show that tectonic movements, sharp changes in climatic conditions and orographic barriers determine extant biogeographical boundaries. These factors lead to abrupt zoogeographical transitions when they act in concert, but their prominence varies across the globe. Clear differences exist among boundaries representing profound or shallow dissimilarities between faunas. Boundaries separating zoogeographical regions with limited divergence occur in areas with abrupt climatic transitions. In contrast, plate tectonics determine the separation between deeply divergent biogeographical realms, particularly in the Old World. Our study reveals the multiple drivers that have shaped the biogeographical regions of the world.

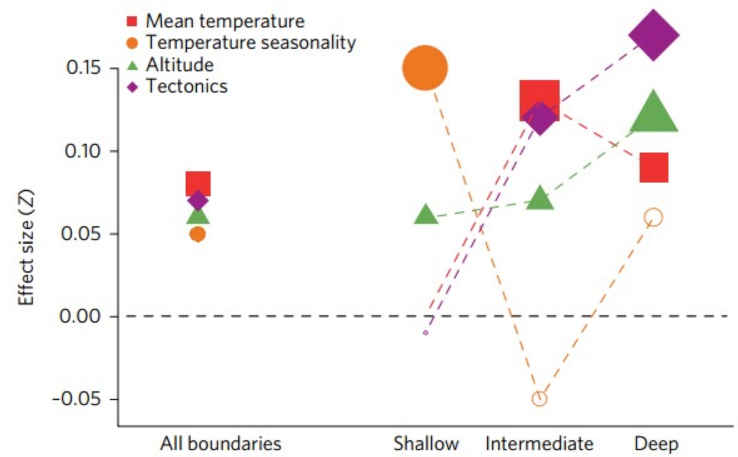


Figure 2 | Relative importance of plate tectonics, altitude and climate on the boundary positions of the biogeographical regions worldwide. The figure presents the effect sizes (obtained through autoregressive models) of each factor in explaining all boundaries and the boundaries between shallow, intermediate and deep bioregions (19, 11 and 6 bioregions, respectively). The size of symbols is proportional to effect size; empty symbols represent non-significant values. Effect size was measured using Fisher's Z, which allows for comparison among analyses, even if they have different sample sizes[62].

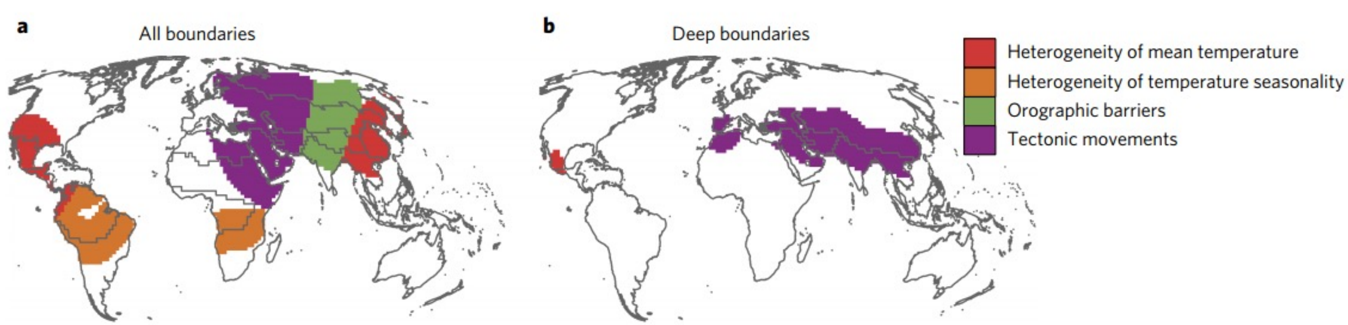


Figure 4 | Factors most strongly related to the presence of biogeographical boundaries. For each pixel, the map shows the factor with the highest local effect size according to GWR. **a**, Analysis on all the boundaries. **b**, Analysis limited to the deep boundaries. Only local effect sizes significantly higher than zero are mapped.

Concepts of biogeography

Biogeographical regions can be quantitatively characterized with the help of **indexes of similarity**

	North America	West Indies	South America	Africa	Eurasia	New Guinea	Australia
N. America							
W. Indies	67						
S. America	81	73					
Africa	31	27	25				
Eurasia	48	27	36	80			
New guinea	36	21	36	64	64		
Australia	22	20	22	67	50	93	
Philippines	40	20	32	88	80	64	50

Simpson`s index of similarity:

$$(C/N1) \times 100\ (\%)$$

N1 – number of taxa in the area with the smaller number of taxa;

C – number of taxa in common between the two regions

Concepts of biogeography

Species have defined geographic distribution

Endemic species (or taxa) – species with a limited spread in a particular area. Endemic spread can be more or less widespread

Saaremaa rattlebox (*Rhinanthus osiliensis*)

neoendem – post-LGM

Madagascar lemurs

Devil`s Hole pupfish (*Cyprinodon diabolis*) - *microendem – VERY narrow area*

Cosmopolitan species (or taxa) – distributed all over the world pigeon and composite plants (dandelion) – in all continents except Antarctic

Concepts of biogeography

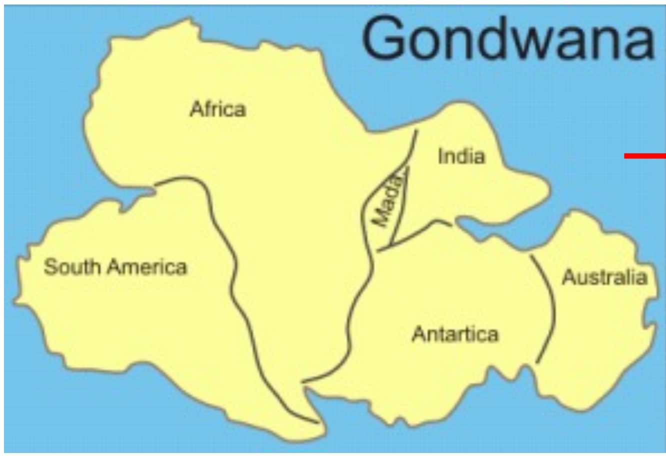
Spread area of the species can be:

- **Continuous;**
- **Disjunct (fragmentary);**
  - jump dispersal disjunction;
  - evolutionary disjunction;
  - climatic disjunction;
  - geological disjunction

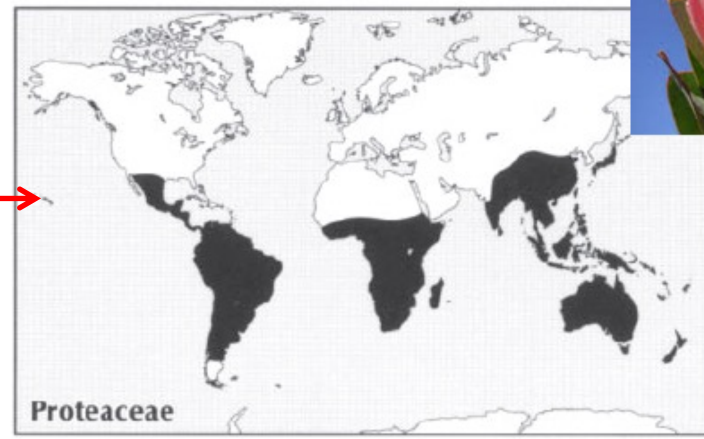
- **Relict groups**: because of climatic and evolutionary reasons once widely spread species inhabitate today only restricted area

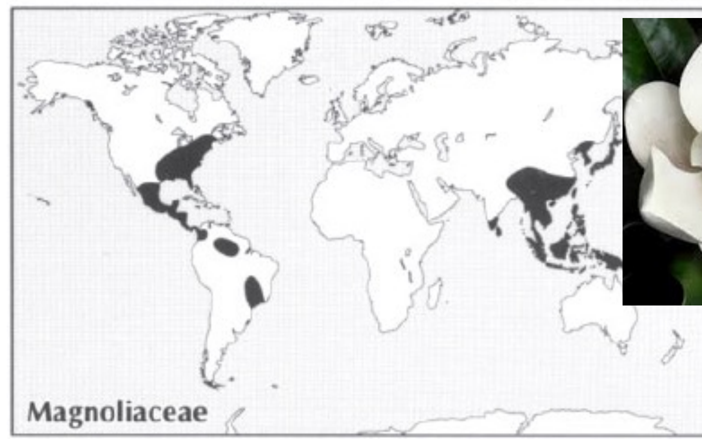
Concepts of biogeography

Geological disjunction – continental drift



510-180 MAT





Climatic – Ice Ages during last 2 My pushed Magnolias to the south

Evolutionary – once widely spread species derives into two separate species in the distant parts of the area and disappears from the centre – *Acacia, Ficus*

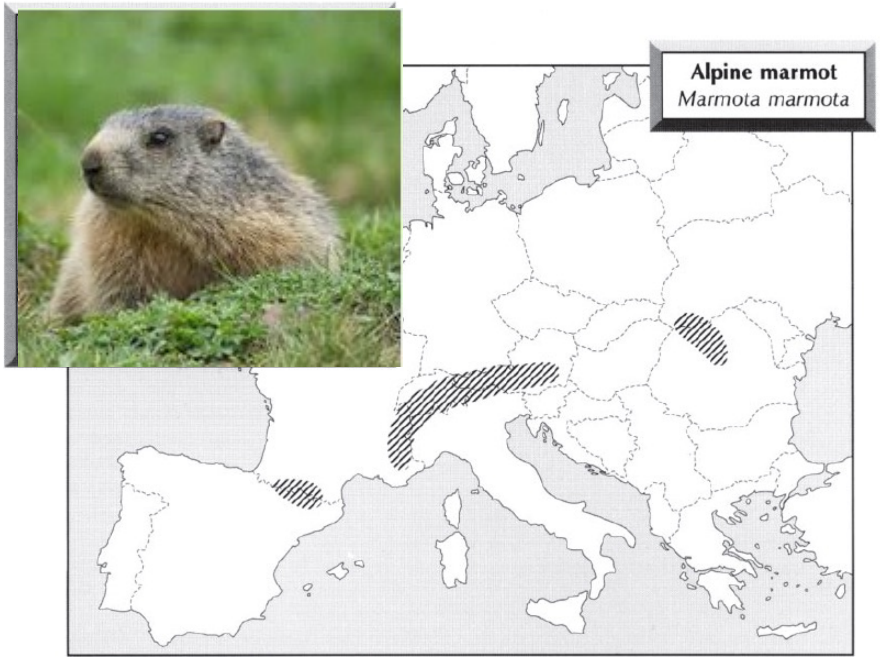
Bubulcus ibis

Jump disjunction – new spread area, distant from the original one is inhabited during the life-time of an individual – seeds, <u>storms</u>, sp. travelling together with people

Concepts of biogeography

Relict groups

Alpine marmot – was once widespread on the plains of Central Europe. After the climate got warmer, it has a patchy distribution at 1000-2500 m altitude in Alps, Carpathian Mountains and Pyrenees – **climatic relict**



Tuatara (Spenodon punctatus) – endemic species in New Zealand, the only one in order *Rhynchocephalia* that flourised *ca* 200 Mya and is today distantly related to lizards and snakes – **evolutionary relict.**

Factors that influence the distribution of species

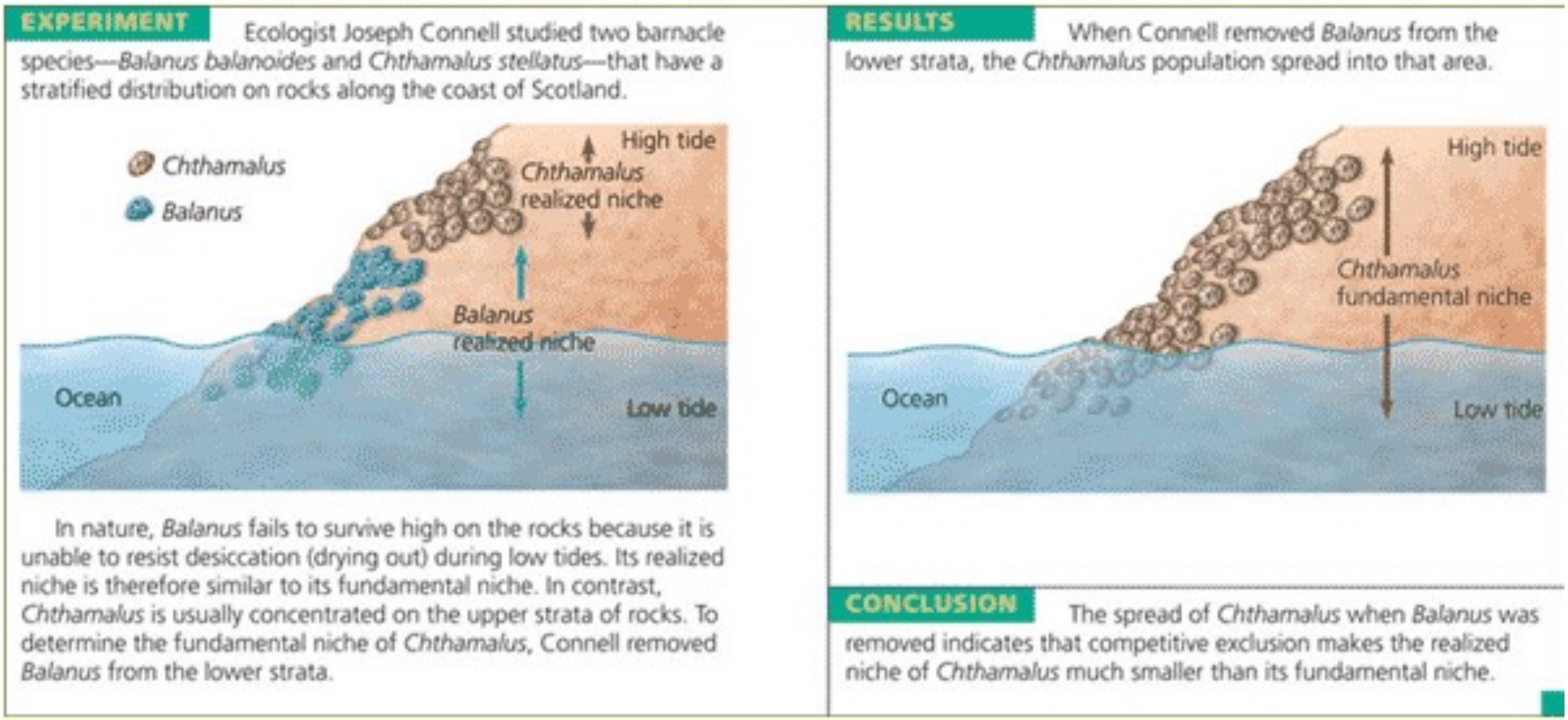
- **ecology** - environmental factors, both abiotic and biotic;
- **history** – demographic history of a species
- **climate** – Ice Ages;
- **geological processes** - plate tectonics

http://www.adpress.be/environnement

Factors that influence the distribution of species

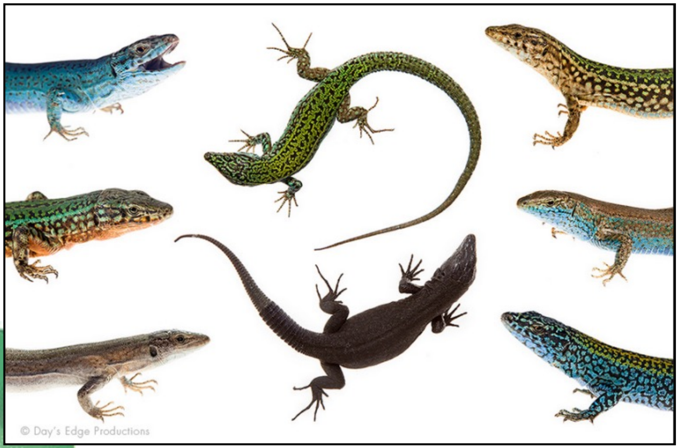
Ecological restrictions – depend on suitable environmental conditions. Every species has a **fundamental** niche - every possible niche that the species may occupy; and a **realized** niche – the actual niche within the possible niche. As a rule, the first one is smaller that the second – **due to a competition between species**

Barnacles



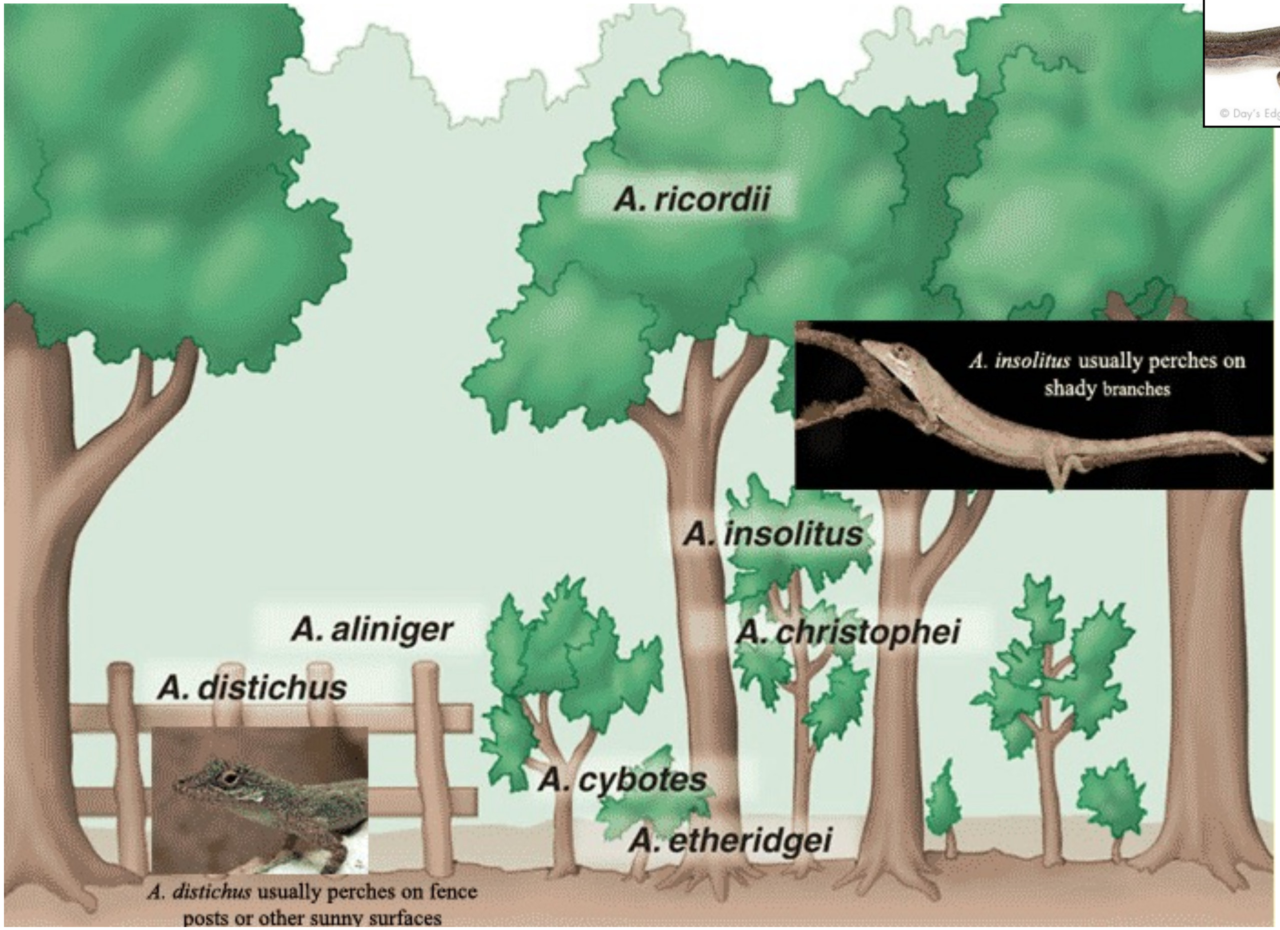
Historical restrictions – linked with the demographic history of a species. For example, species has never reached to the area, although the environmental conditions are OK.

Species diversification on a local scale – adaptive radiation on island archipelagos – **ecology and history**



Anolis sp. Islands of Carribean

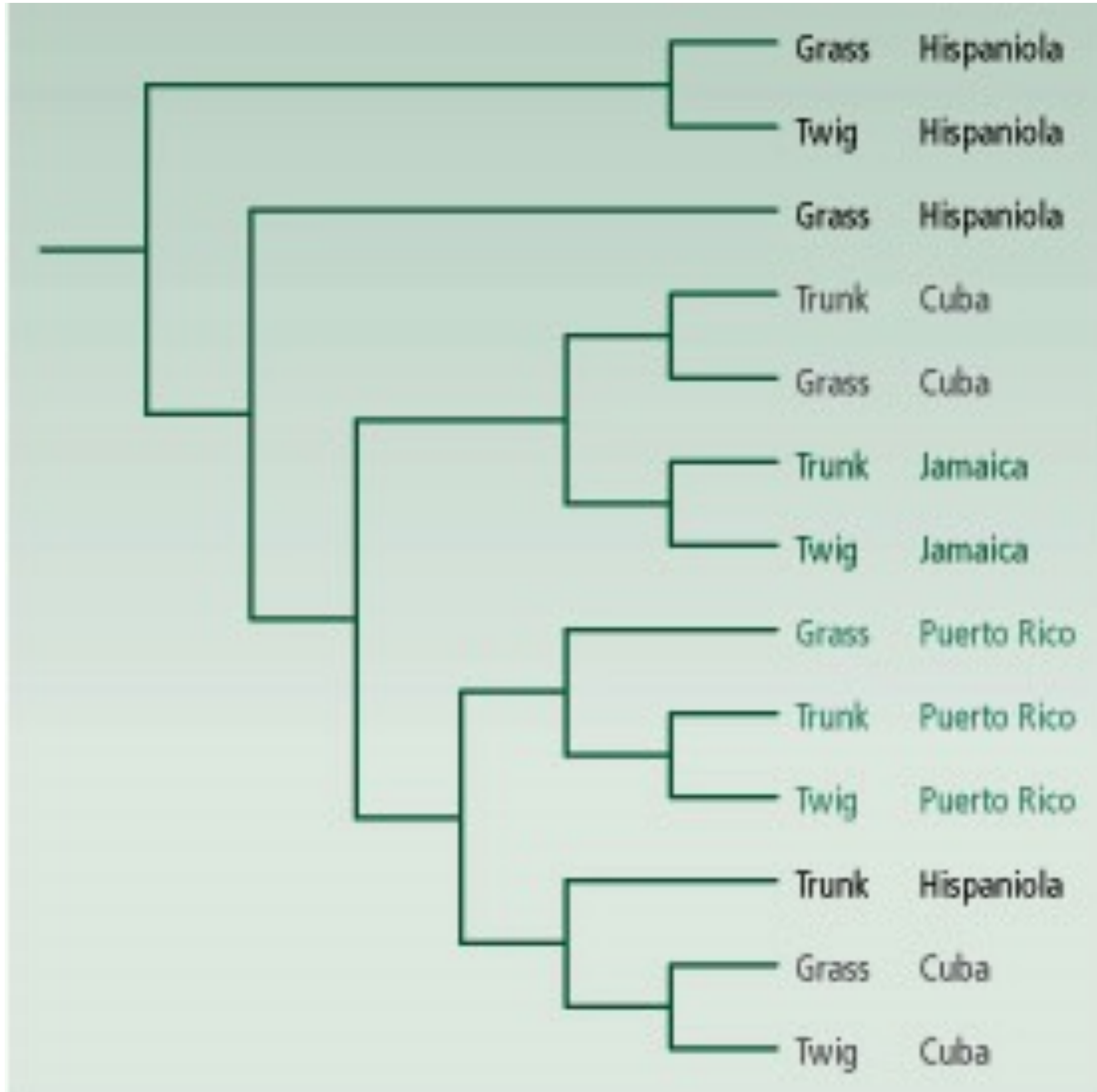
Competition for resources, niche adaptation



Adaptive radiation – ancestral species evolves into a number of descendant species, each with distinct **ecological** adaptation

Species diversification on a local scale – adaptive radiation on island archipelagos – **ecology and history**

Figure 17.5
Phylogenetic relations of different ecological types of species of lizards (*Anolis*) on four Caribbean islands. The full results are for six ecological types, of which only three are shown here (grass, twig, and trunk). The other three, however, illustrate much the same pattern. Each ecological type tends to have evolved independently on different islands: the phylogeny groups species by island more than by ecological type. The phylogeny was produced by parsimony, using mitochondrial DNA sequences from the lizards. Modified from Losos *et al.* (1998).

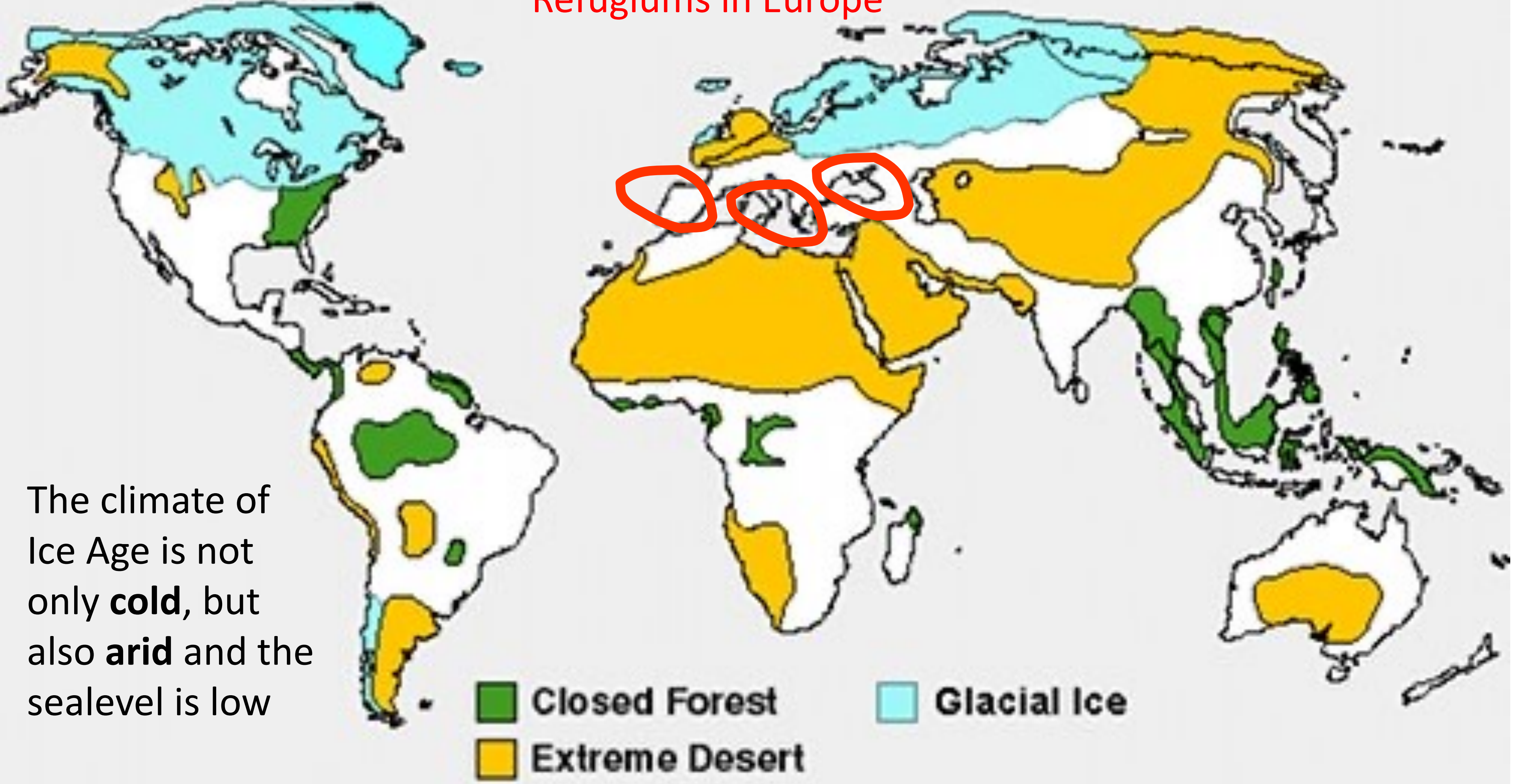


Adaptations arise in each island due to the local competition for habitats – species of one island are more closely related with each other than with similar forms (trunk-, grass-living) of other island

Sympatric specification – one area, occurs due to ecological factors

Last Glacial Maximum (LGM)

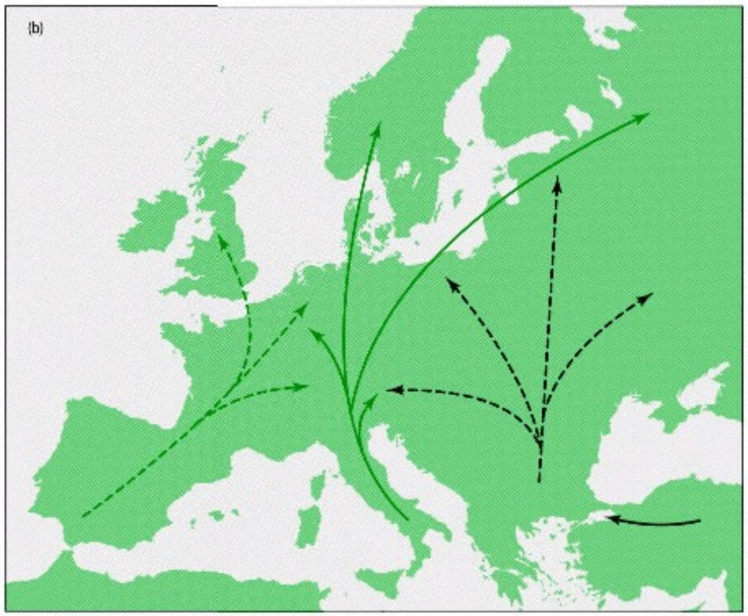
Refugiums in Europe

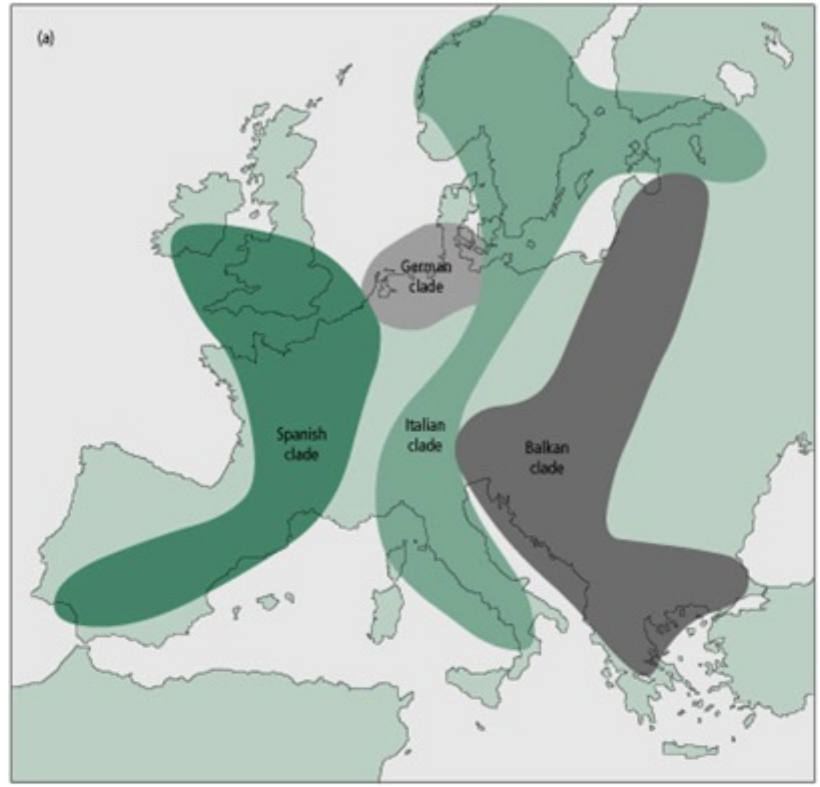


The climate of Ice Age is not only **cold**, but also **arid** and the sealevel is low

Refugiums have a strong influence on the biological diversity
Dispersal from refugiums creates **hybrid zones** between species

Species diversification due to climatic changes - an example of post-LGM spread of hedgehogs in Europe

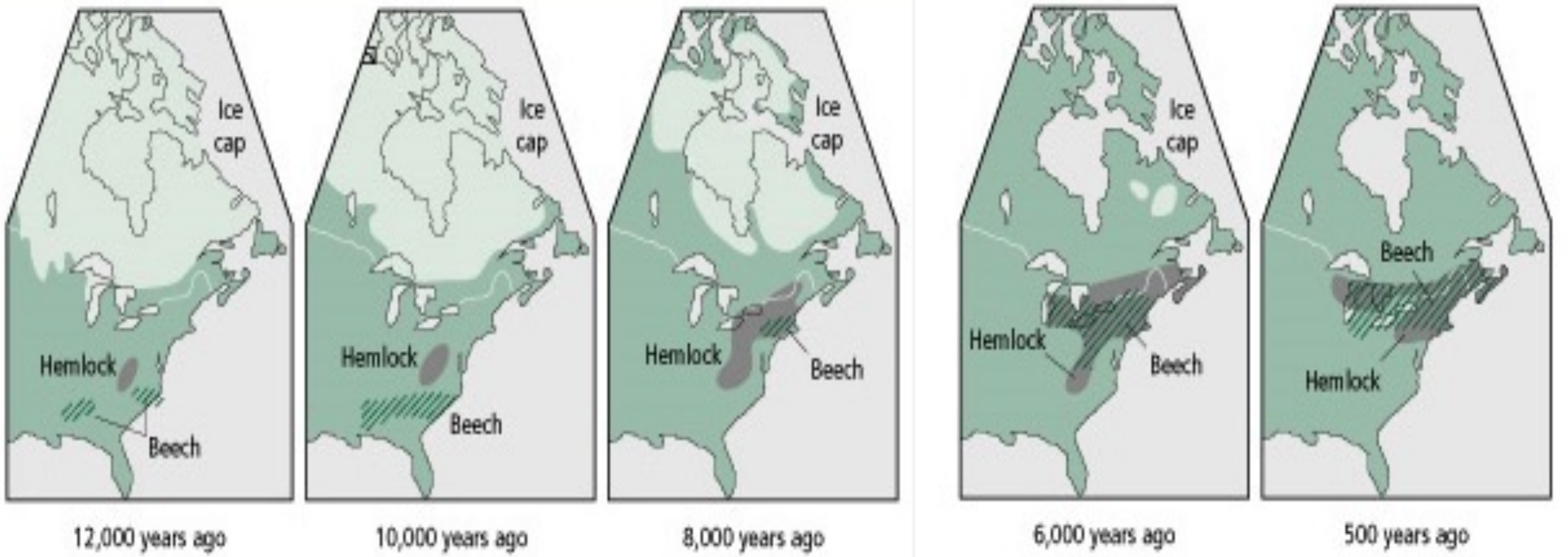




Split between species (common and southern hedgehogs (*Erinaceus)* occurred already *ca* 3 Mya, LGM *ca* 20 kya leaded to a further diversification within species in different refugiums

Figure 17.4
(a) Distribution of the main genetic clades of hedgehogs (*Erinaceus* species) in Europe. They are currently classified into two species, but the two probably hybridize.

Species diversification due to climatic changes - an example of post-LGM spread of plants in North America (pollen analysis)



Tsuga (hemlock)

Fagus (beech)

Species diversification due to climatic changes - many species follow the same or very similar patterns

Hewitt et al. 2000, Science

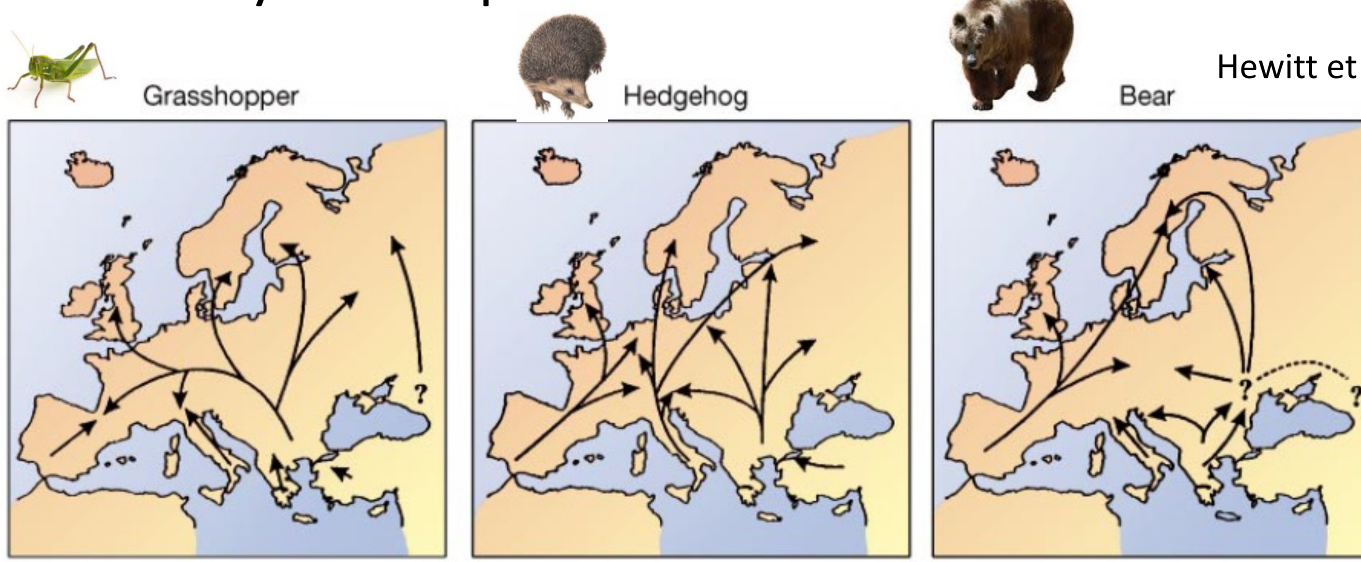


Figure 2 Three paradigm postglacial colonizations from southern Europe deduced from DNA differences for the grasshopper, *Chorthippus parallelus*, the hedgehog, *Erinaceus europeus/concolor*, and the bear, *Ursos arctos*. The main refugial areas, Iberia, Italy, the Balkans and Caucasus, contributed differently to the repopulation of northern parts.

Dispersal from refugiums creates **hybrid zones** between species

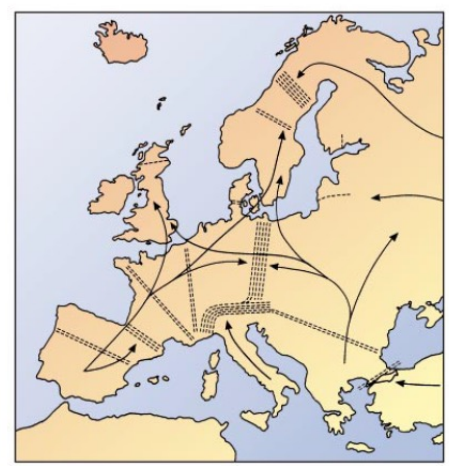


Figure 3 The general position of some well-known hybrid zones in Europe, which show major clustering in Scandinavia, central Europe and the Alps. Other clusters are apparent in the Pyrenees and the Balkans. These suture zones are caused by commonalities of ice-age refugia, rate of postglacial expansion and physical barriers. There is further subdivision in the southern regions.

Species diversification – convergence

Species of large geographic areas tend to be more closely related to other local species than to ecologically similar species elsewhere in the globe. Similarities develop independently because of similar environmental conditions – **convergence**

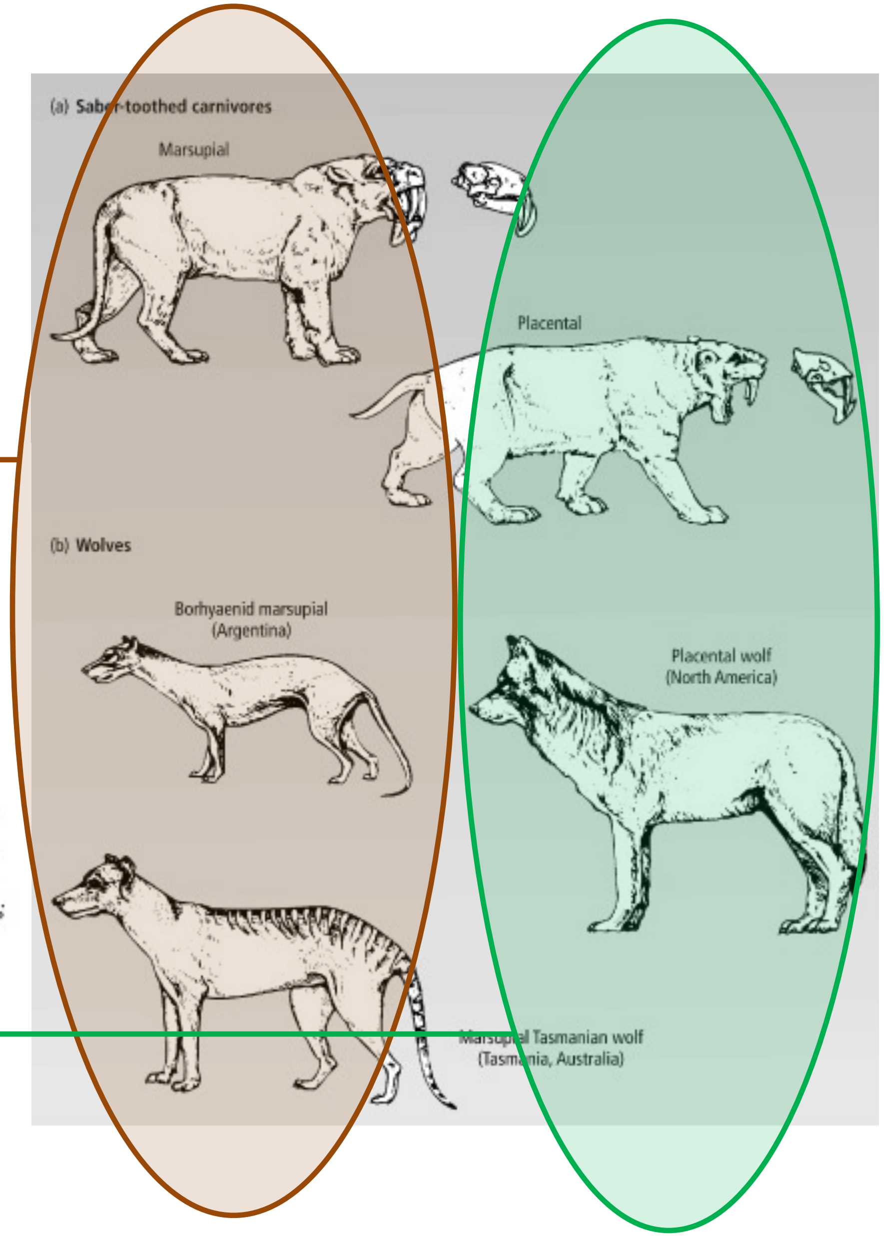
Mediterranean type of ecosystem (adaptations to extreme dryness)

On local scale we had a similar example of *Anolis sp.* inhabiting different island niches

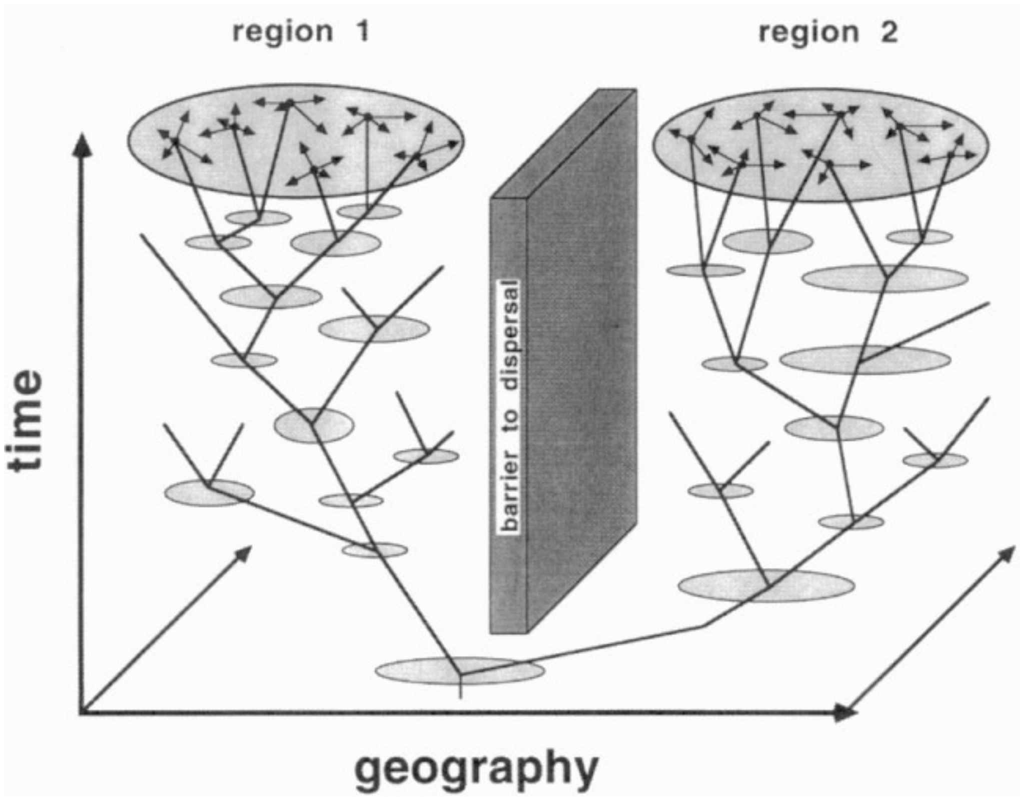
Species diversification – convergence

Morphological similarities between distantly related individuals evolve as a response to similar environmental factors

Figure 15.4
Convergence in marsupial and placental carnivores. (a) The reconstructed bodies and skulls of *Thylacosmilus*, a saber-toothed marsupial carnivore that lived in South America in the Pliocene and of *Smilodon*, a saber-toothed placental carnivore from the Pleistocene in North America. (b) *Prothylacynus patagonicus*, a borhyaenid marsupial from the early Miocene in Argentina; *Thylacinus cynocephalus*, the extinct marsupial Tasmanian wolf; and *Canis lupus*, the modern placental wolf. From Strickberger (1990). © 1990 Jones & Bartlett Publishers.



Phylogeography



Fields of phylogeography:

Strict sense – analyses the spatial distribution of allels with known relationships;

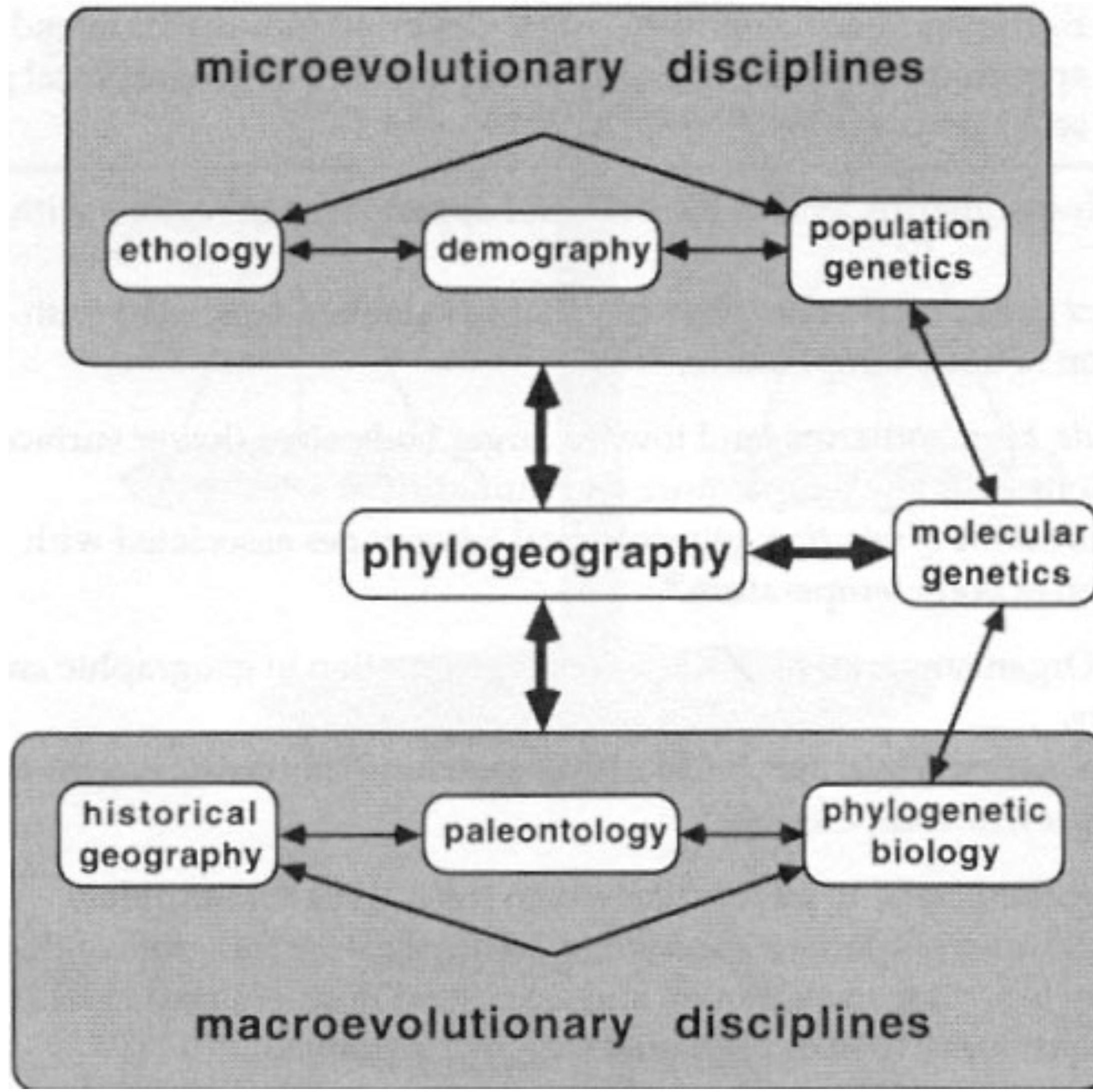
Wide sense – analyses the spatial distribution of any genetically determined trait (morpological, behavioural *etc.*)

The main dimensions of phylogeography are the **time** and **space**

Phylogeography

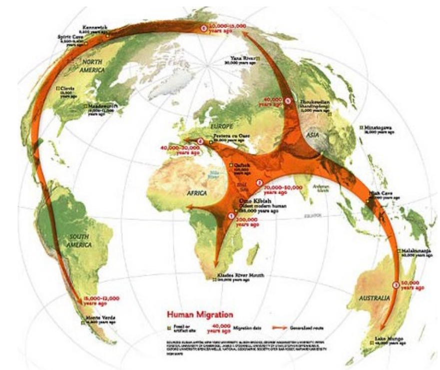
Phylogeography is an interdisciplinary:

- molecular genetics;
- population genetics;
- demography;
- paleontology *etc*.



Distribution of species

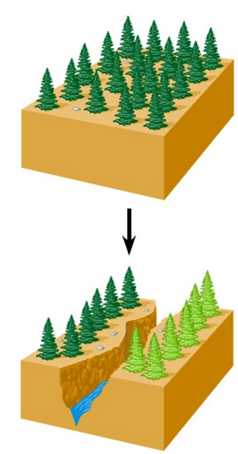
There are two major type of events (models) behind the spread of species and their biological diversification:



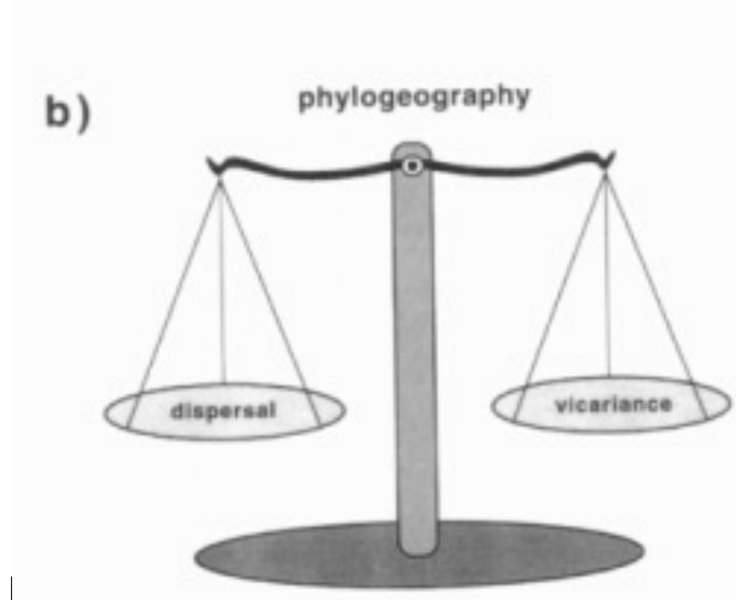
1) dispersal – search for new niches, retreat and/or recolonization, genetic drift in new sub-populations

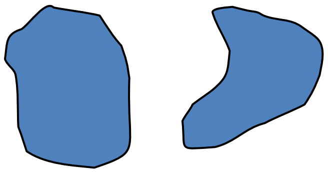
- corridors
- filtering bridges
- sweepstake – accidental and risky distant spread – recolonization of islands after catastrophes (Krakatau in Indonesia)

2) vicariance (from Latin *vicis*; change) - process by which the geographical range of an individual taxon or a whole biota is split into discontinuous parts by the formation of a physical or biotic barrier (*allopatric specification*)



Phylogeography helps to weight the influences of different models

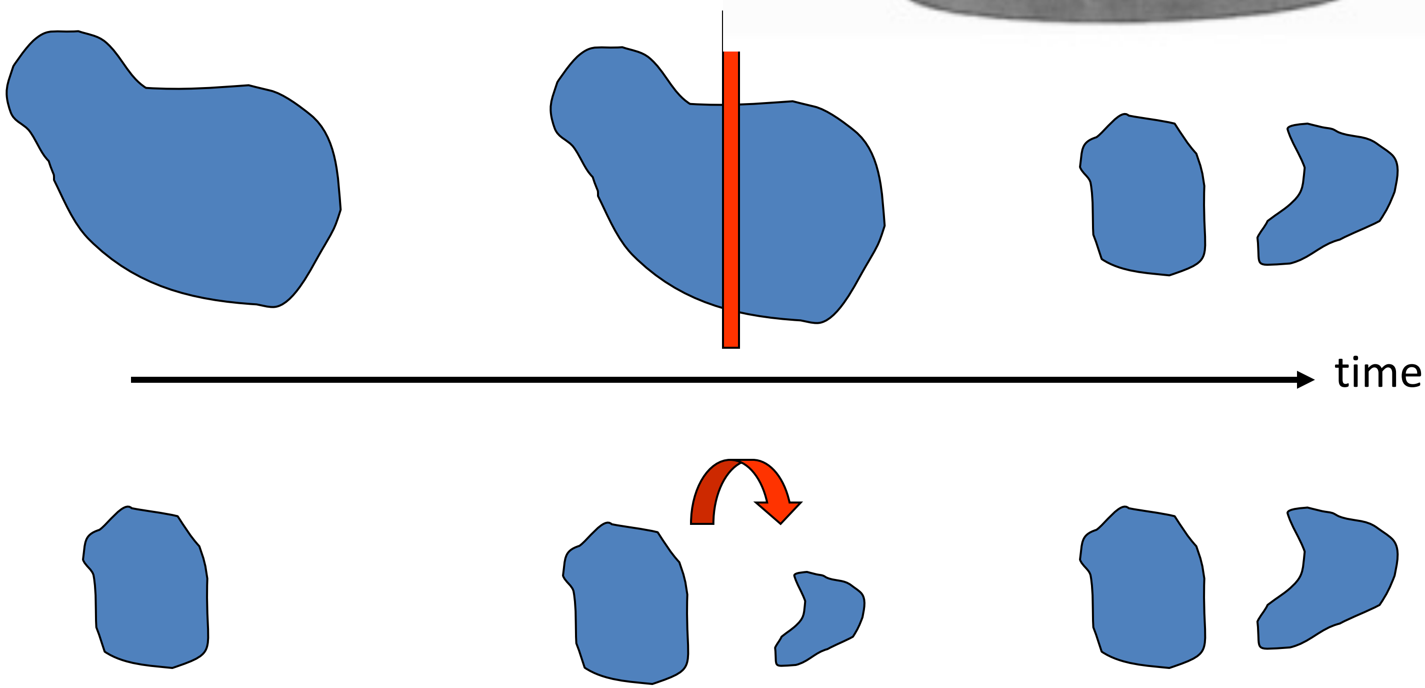




How did the diversity evolve?

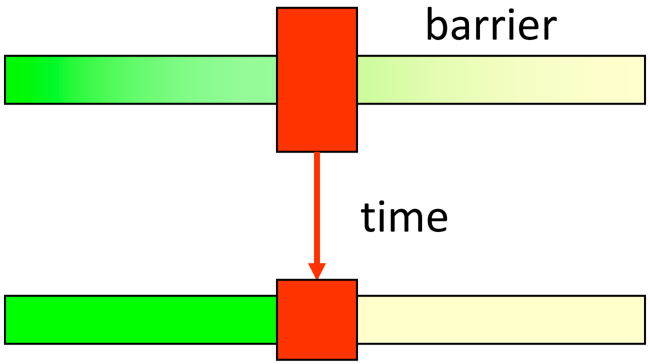
Vicariance

Dispersal



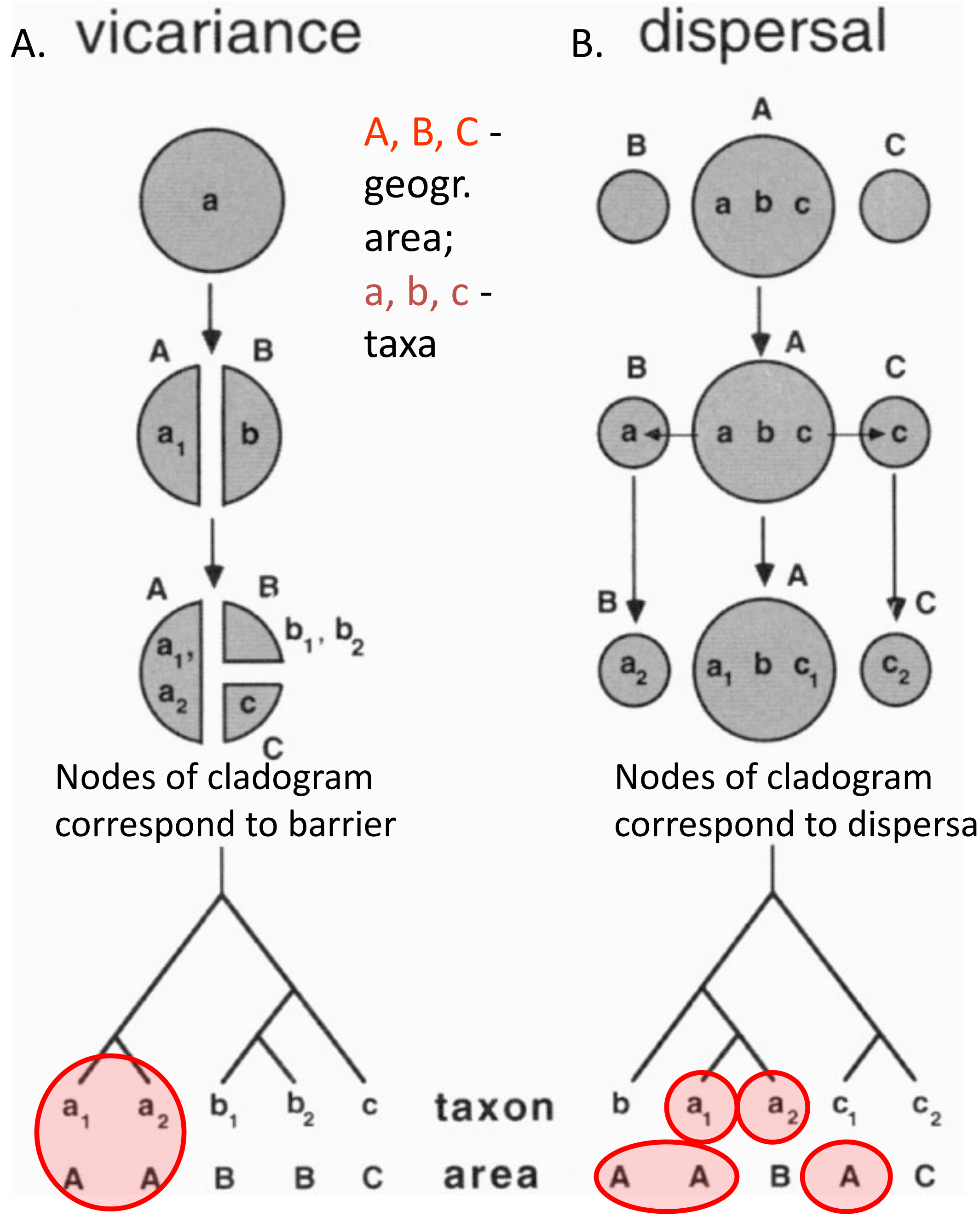
Phylogeography helps to weight the influences of different models

A.



B.

Geographical cline – smooth change of allele frequencies in space



Phylogeography helps to weight the influences of different models

Alternative models for speciation

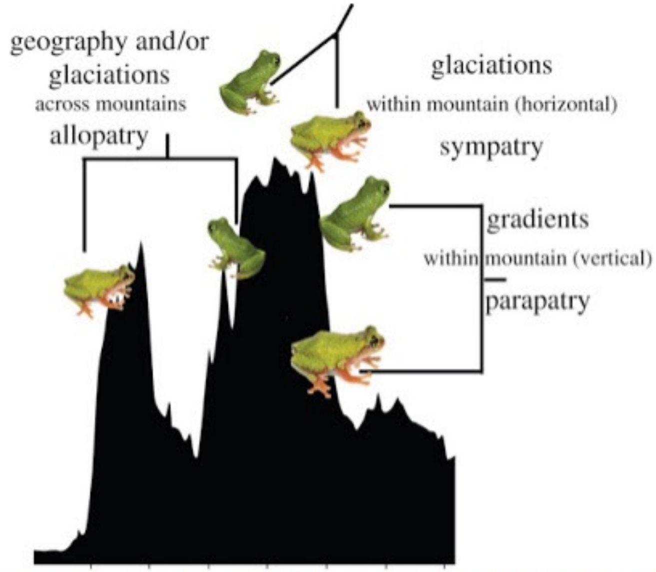
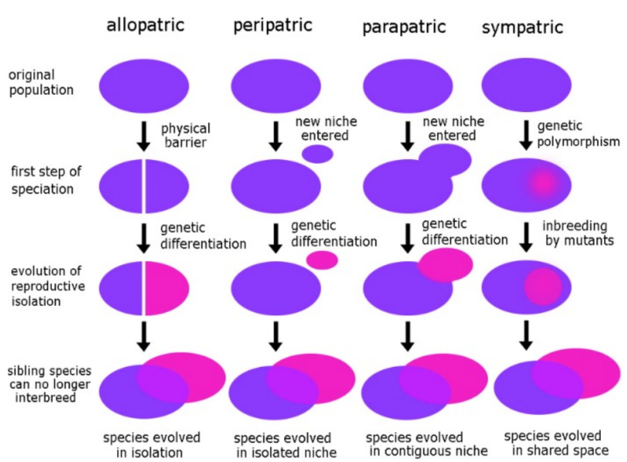


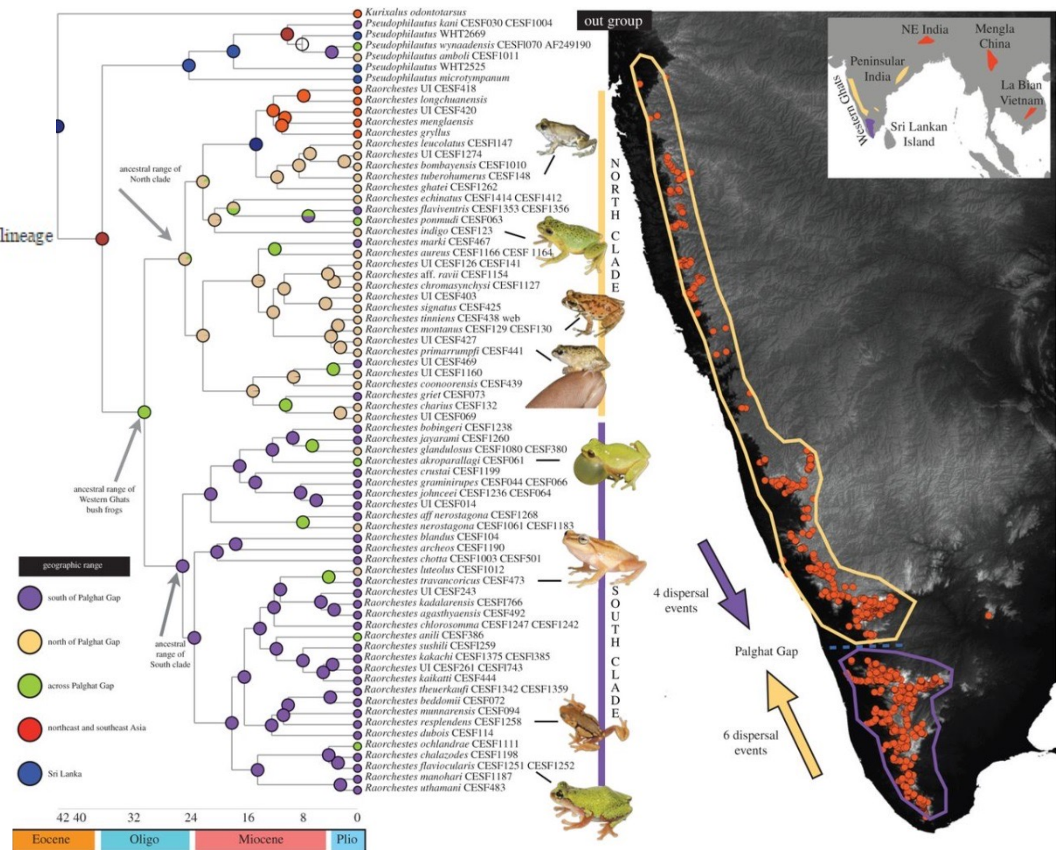
Figure 1. Alternative processes driving diversification in a mountain setting and expected patterns of sister-lineage distributions (summarized in the electronic supplementary material, table S1).



Bush frogs *Raorchestes* and *Pseudophilautus* of Peninsular Indian western mountain range

I. Ancient vicariant event separated north and south clade

Vijayakumar *et al.* 2016



Phylogeography helps to weight the influences of different models

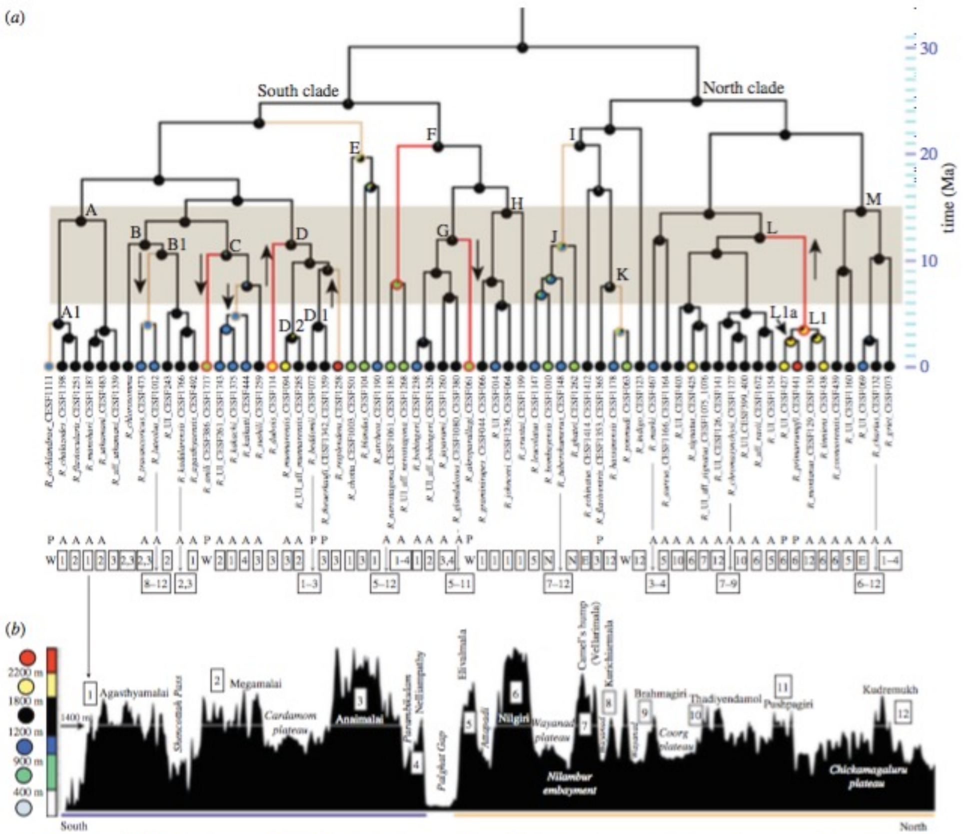
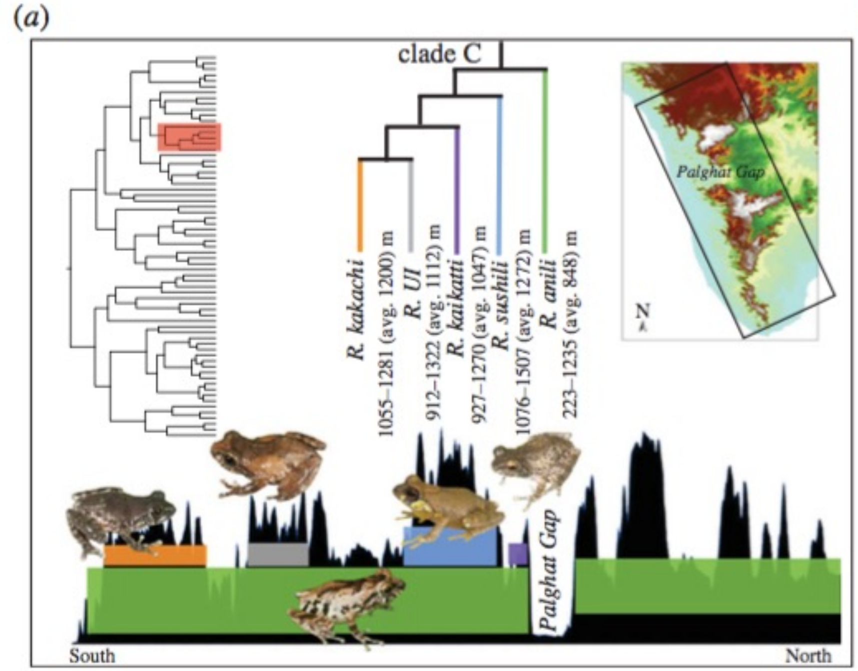


Figure 4. Zone of origin of bush frogs and historical transitions along an elevational gradient. Colours refer to the elevational zones (see (*b*)). In the case of transitions inferred using both six and three zones, the branches are coloured in red and transitions seen using only six zones are shown in brown. The shaded region corresponds to Late and Mid-Miocene. (*a*) Geographical range of bush frog lineages indicated by a number corresponding to major massifs in (*b*). Distribution: A, allopatric; P, parapatric; W, widespread; N and E, northern Western Ghats (WG) and eastern isolated massifs (not illustrated in (*b*)). (*b*) Elevational (cross-section) profile of the WG Escarpment.



Vijayakumar *et al.* 2016

II. Specifications in local level to different ecological niches (*e.g.* altitude)

Phylogeography – genealogical concordance

Genealogical concordance - genealogical data from different sources (genetic markers) give the same results within species and between species of the same region and are in agreement with other biogeographic data

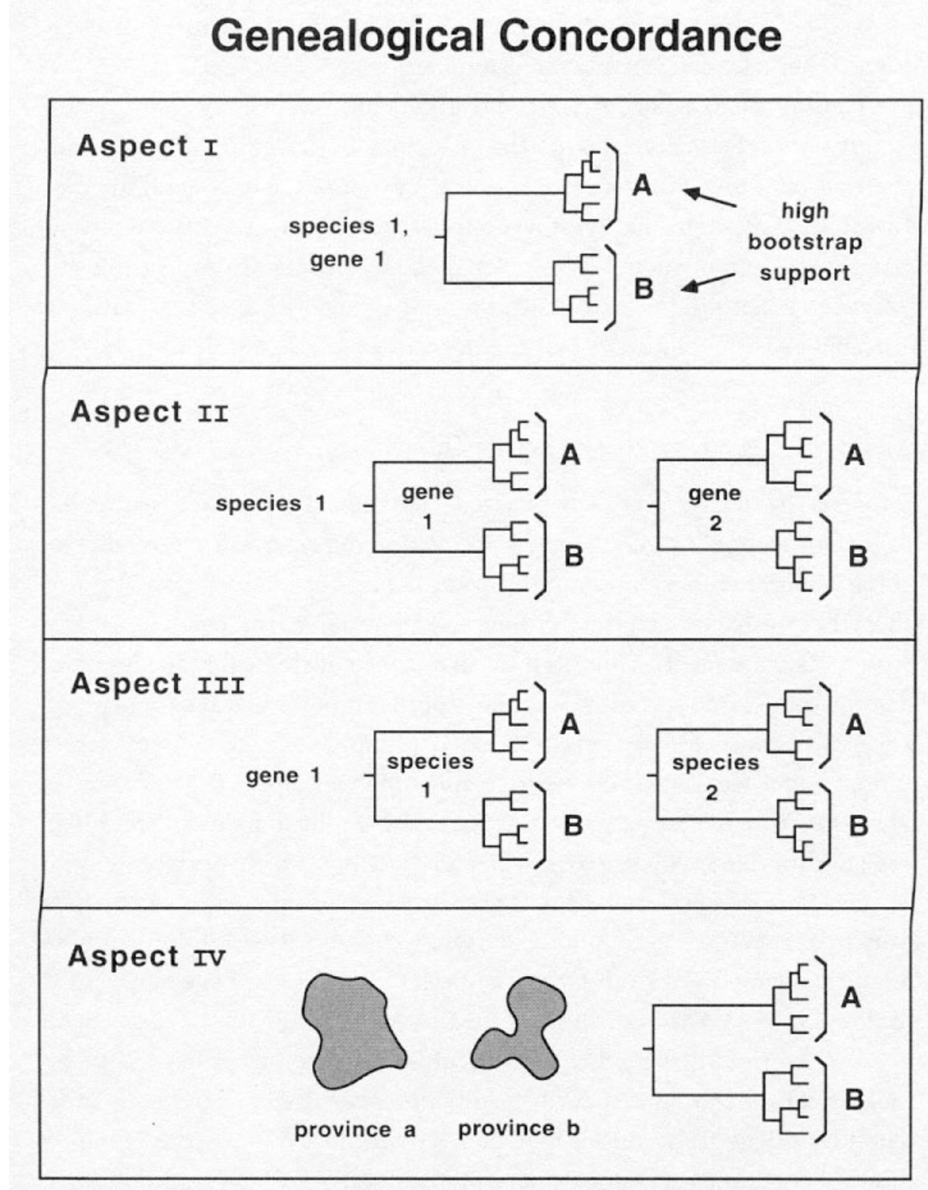


FIGURE 5.1 Schematic presentation of four distinct aspects of genealogical concordance (see text and Table 5.1 for further explanation). "A" and "B" are distinctive phylogroups in a gene tree.

Phylogeography – genealogical concordance

1) **Gene level** – is there a statistical support for putative gene-tree clades?

2) **Species level** – do the gene-tree partition of different loci tell the same story within a population or species (considering different mutation rates of loci)?

3) **Geographic level** – do the partitions of gene-trees of different codistributed species have the same spatial pattern (because of the influence of the same biogeographical factors shaping their phylogenies)?

4) **Biogeographical level** – do the partitions of gene-trees of several species of a biogeographic region tell the same story?

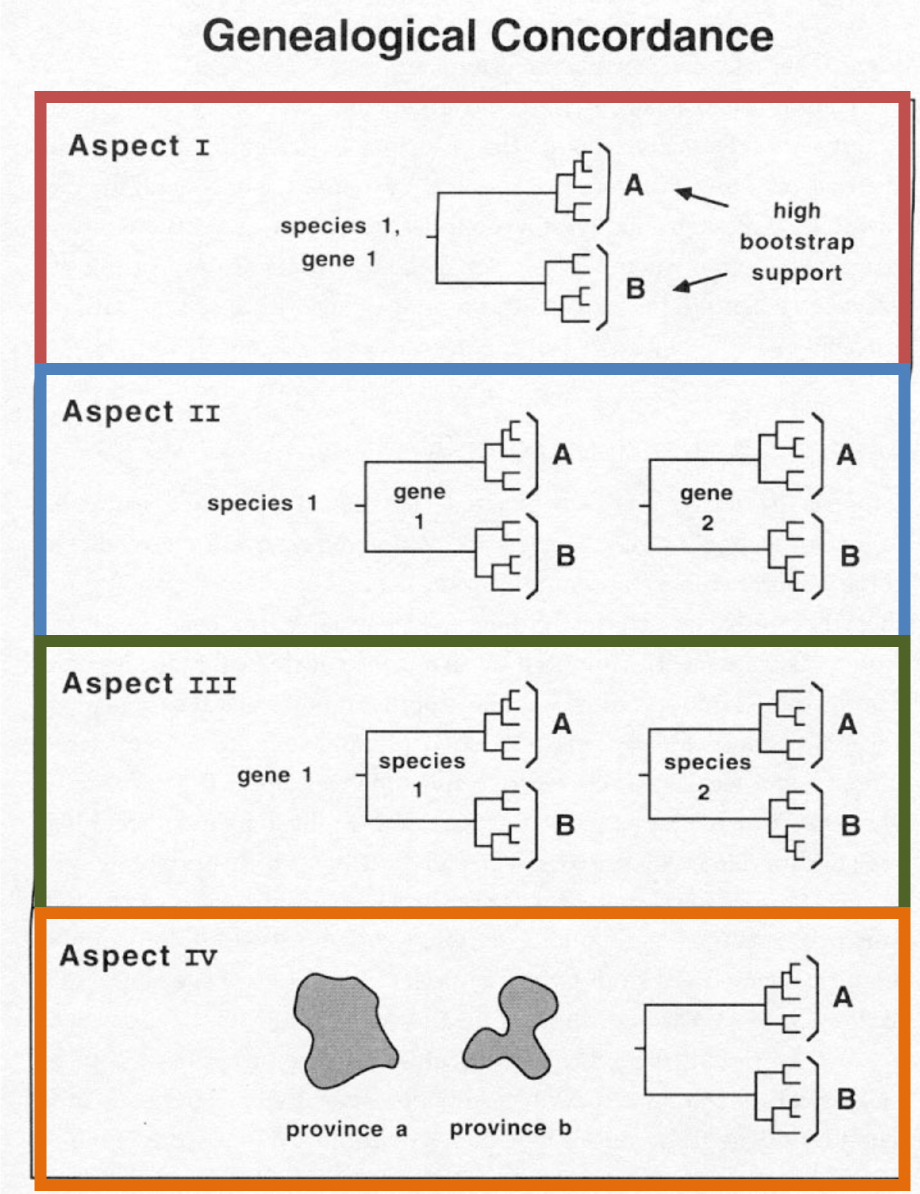


FIGURE 5.1 Schematic presentation of four distinct aspects of genealogical concordance (see text and Table 5.1 for further explanation). "A" and "B" are distinctive phylogroups in a gene tree.

Phylogeography – genealogical concordance

Spotted sunfish
(*Leptomis punctatus)*

Example of genealogical concordance on different levels: Freshwater species of North American southeast [and also species from the coast (birds, invertebrates)] –

changes of sea-level due to climate, coming and going contacts between water-bodies within last 1,5 My

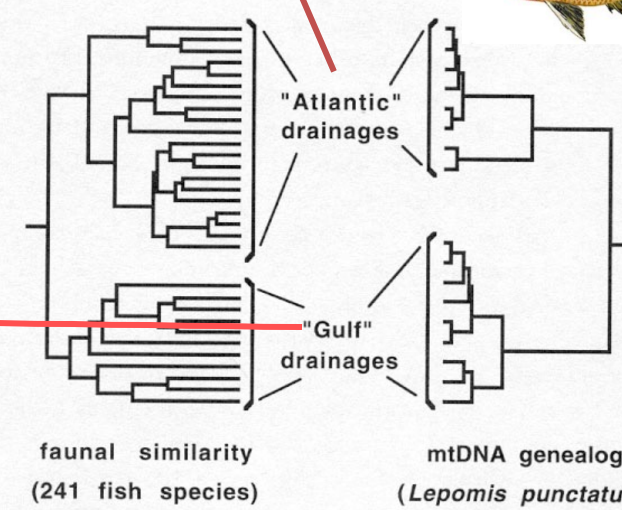


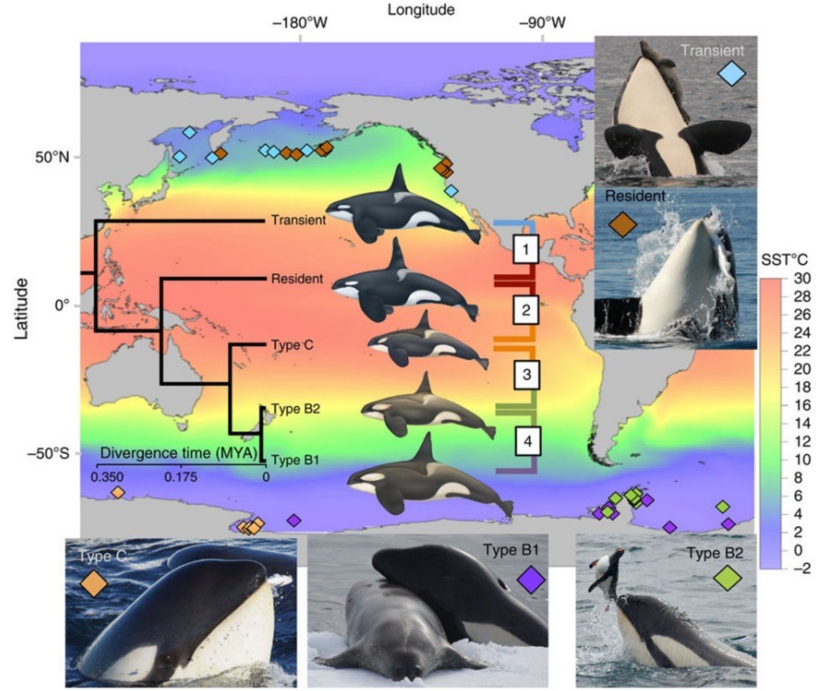
FIGURE 5.7 A clear example of Aspect IV of genealogical concordance (after Walker and Avise, 1998). Geographic distributions of the two major branches in the mtDNA gene tree for the spotted sunfish, *Lepomis punctatus* (Bermingham and Avise, 1986) agree perfectly with the two principal southeastern faunal regions for freshwater fishes (Fig. 5.4).

Foote *et al.* 2016

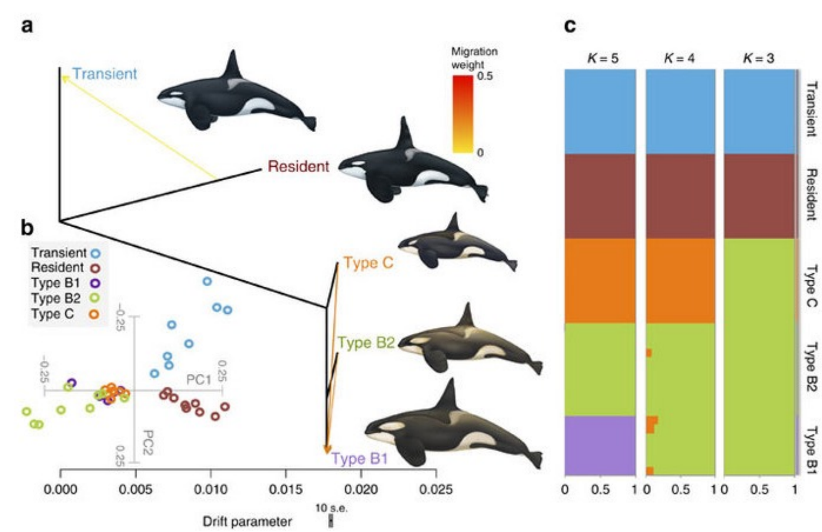
An example of the phylogeographic pattern

Mammals: small terrestrial species are well structured, big and/or mobile species could in principal be usually less differentiated ...

but for example killer whales (*Orcinus orca)* have two genetically and behaviourally different types that are specialized to specific feeding strategies (fishes, sea mammals or penguins).



Sampling locations and inset photographs illustrating favoured prey species are colour-coded by ecotype: '*transient*' (blue) and *type B1* (purple) are predominantly mammal-eating; '*resident*' (brown) and *type C* (orange) are predominantly fish-eating; *type B2* (green) is known to feed on penguins. The map is superimposed on a colour grid of sea-surface temperature (SST). The Antarctic ecotypes primarily inhabit waters 8–16 °C colder than the North Pacific ecotypes. The relationship among these types and their estimated divergence times based on mitochondrial genomes are shown in the superimposed



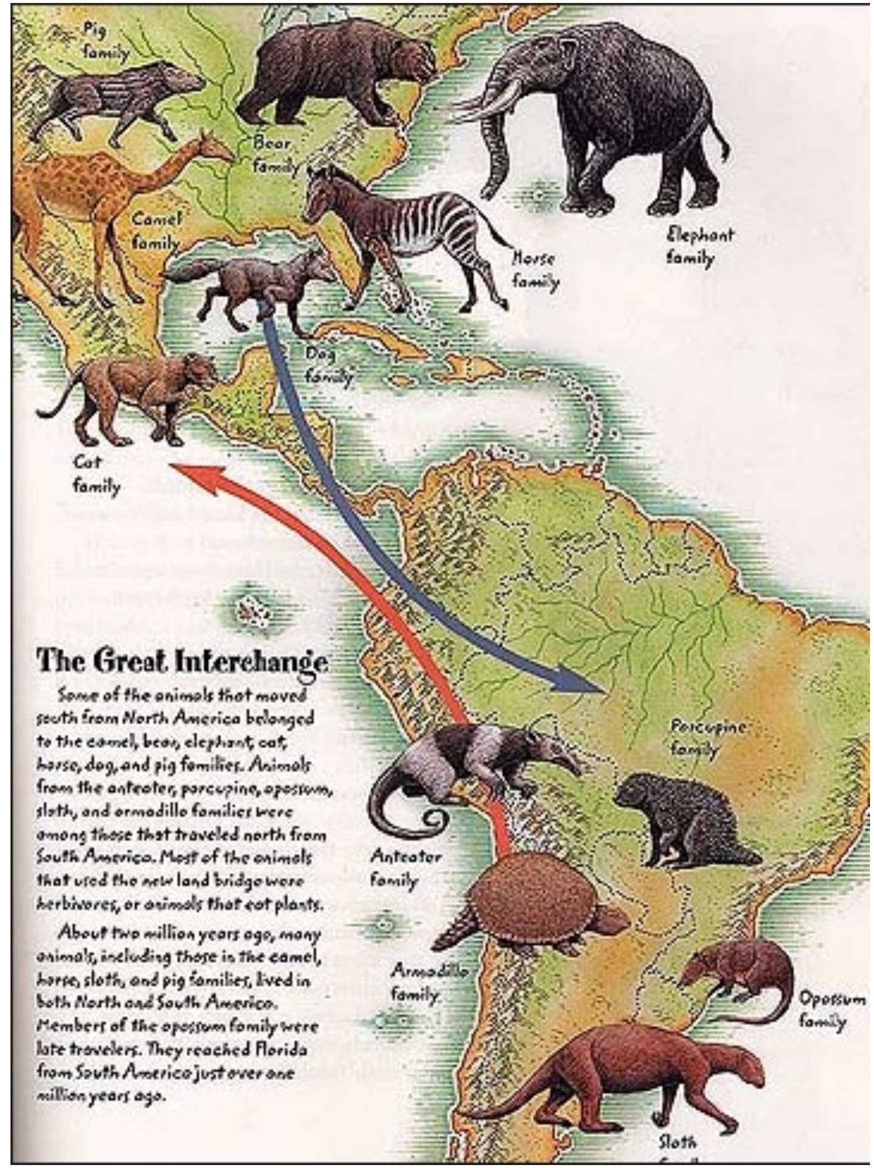
Great American Interchange

One of the most dramatical events in historical biogeography

Continental drift and **reunion** via Panama Isthmus *ca* 3 Mya after being 50 Mya separated

North American triumph:

50% of modern South American mammalian genera are from North America

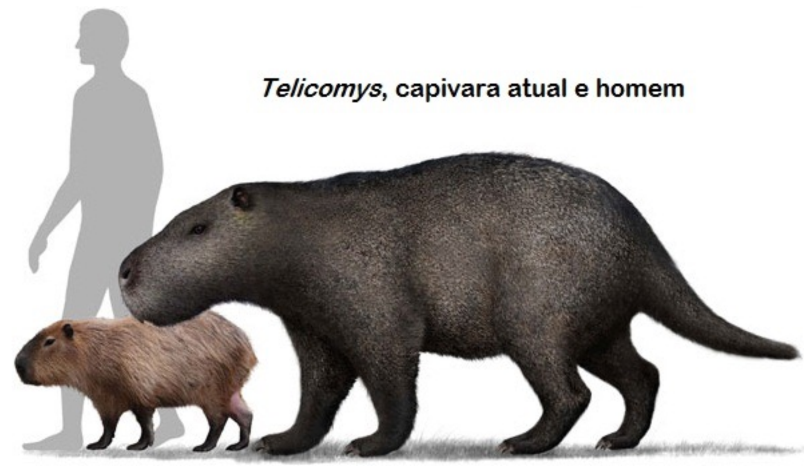


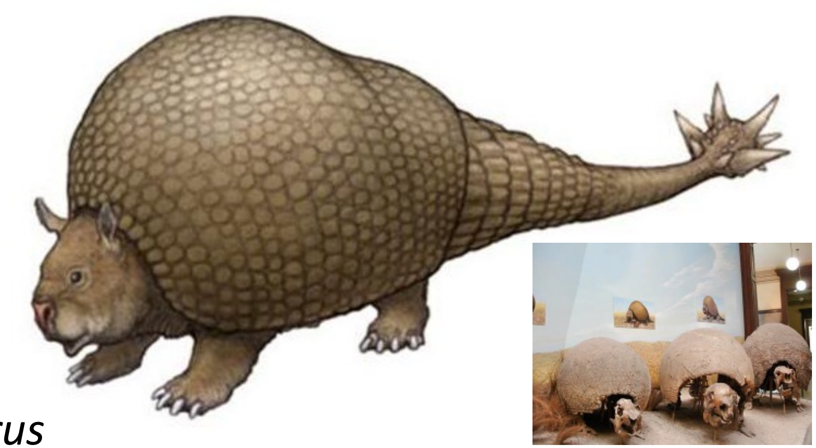
Great American Interchange

South American extinct mammals (Paleocene, Eocene 65 – 34 Mya)

- marsupials (*Marsupiales*);
- xenarthrans (*Xenathra*) – armadillos, sloths);
- ungulates (*Ungulates*)

Megatherion, ground sloth





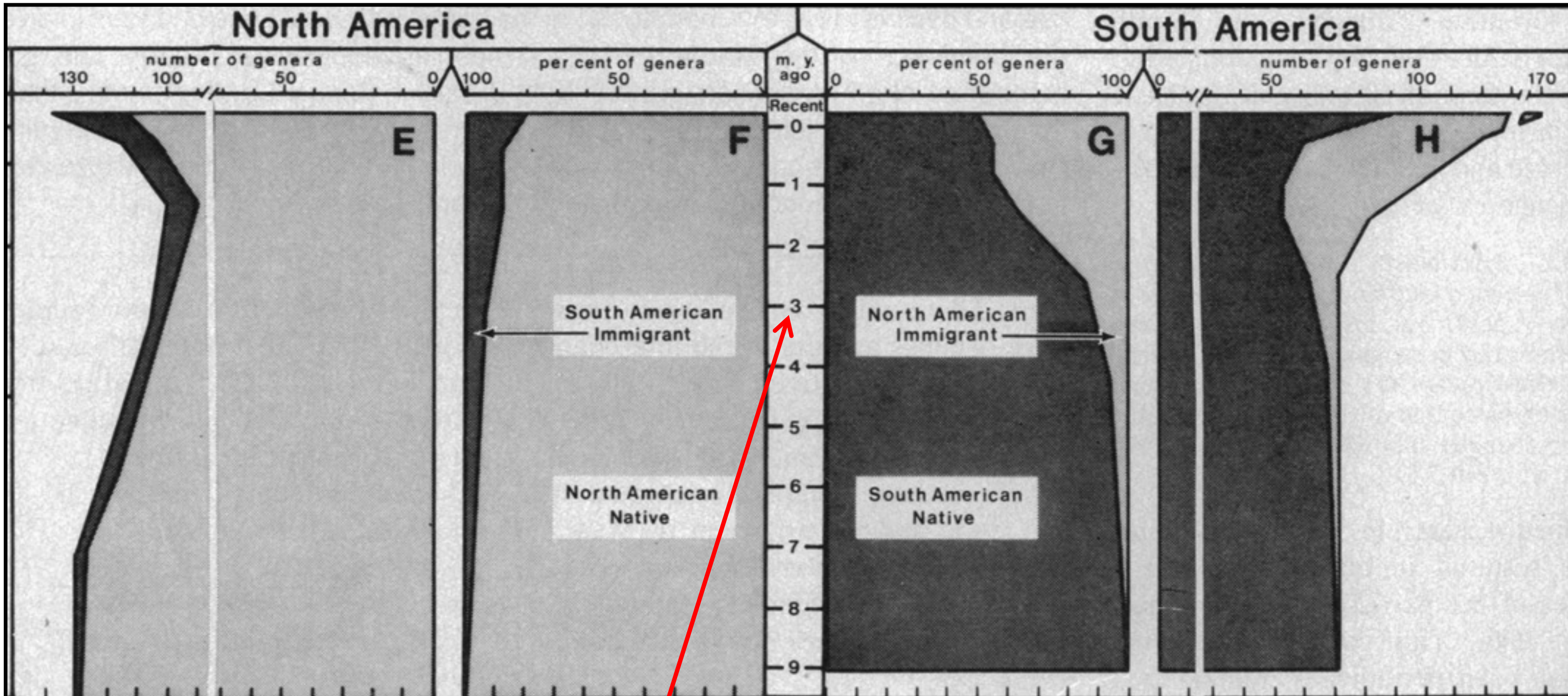
Doedicurus

Great American Interchange

First wave: **Oligocene 34-23 Mya**, step-by-step over the small islands (rodents);
Second wave: **Miocene 8-9 Mya**

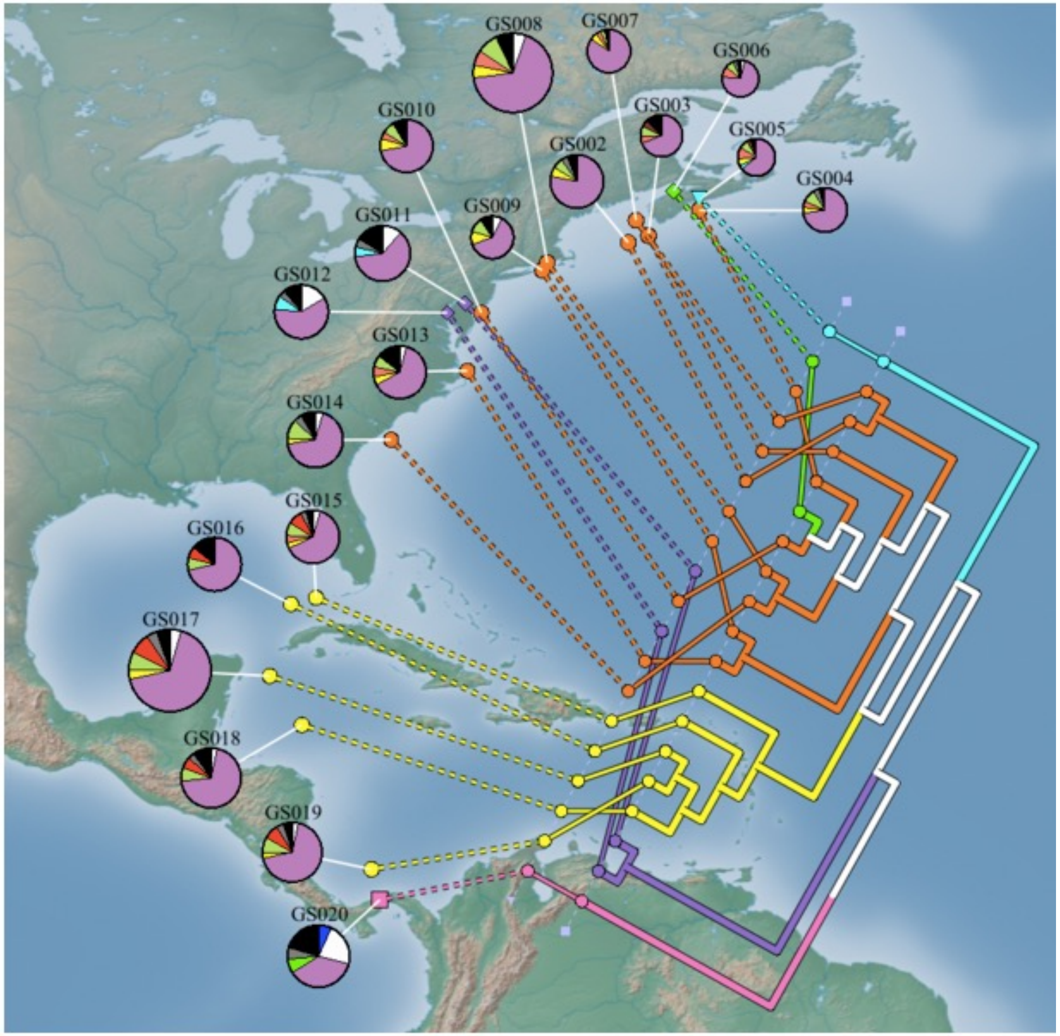
Number and % of genera from different continents

Marshall *et al.* (1982), *Science*



Initial change between continents was equal (*ca* 10%, see 3 Mya), but since 3Mya the North American mammals showed their superiority. Why? Not very clear yet: - have lived a more competitive life in a bigger continent? Faster „Arms race“ and growth of brain size both among predators and prey in North within last 65 My. Climate changes?

Contemporary approaches to biogeography



Biodiveristy of 19 marine metagenomes from the Global Ocean Sampling expedition (Software GenGIS)

GIS – geographic information system connected with databases of your interest (demographic dynamics, nature conservation *etc.*

https://blog.frontiersin.org/2015/05/19/latest-section-biogeography-and-macroecology-now-open-for-submissions/

Summary

Species have a defined **geographic distribution** – it depends both on local conditions (ecological niche) and on (pre)historical events that might have influenced many species at the same time (ice ages, continental drift);

The species with similar or shared characteristics belong to specific **biogeographical regions**

The ranges of species can be altered by **dispersal** and/or **vicariance**

Biogeography has benefitted a lot from the expansion of molecular phylogenetic research – the methods used in **phylogeographical studies** help to reveal the role of the major processes that have shaped the present diversity we see today in natural world