Plant of the Day

Hawaiian Silversword Alliance

- All descended from a common ancestor (an annual herbaceous tarweed
- 30 species in 4.5 - 6 million years
- Trees, shrubs, mat-plants, cushion plants, rosette plants, lianas
- High alpine to near sea level
- Habitats with <4 to >123 cm annual precipitation

Macroevolution

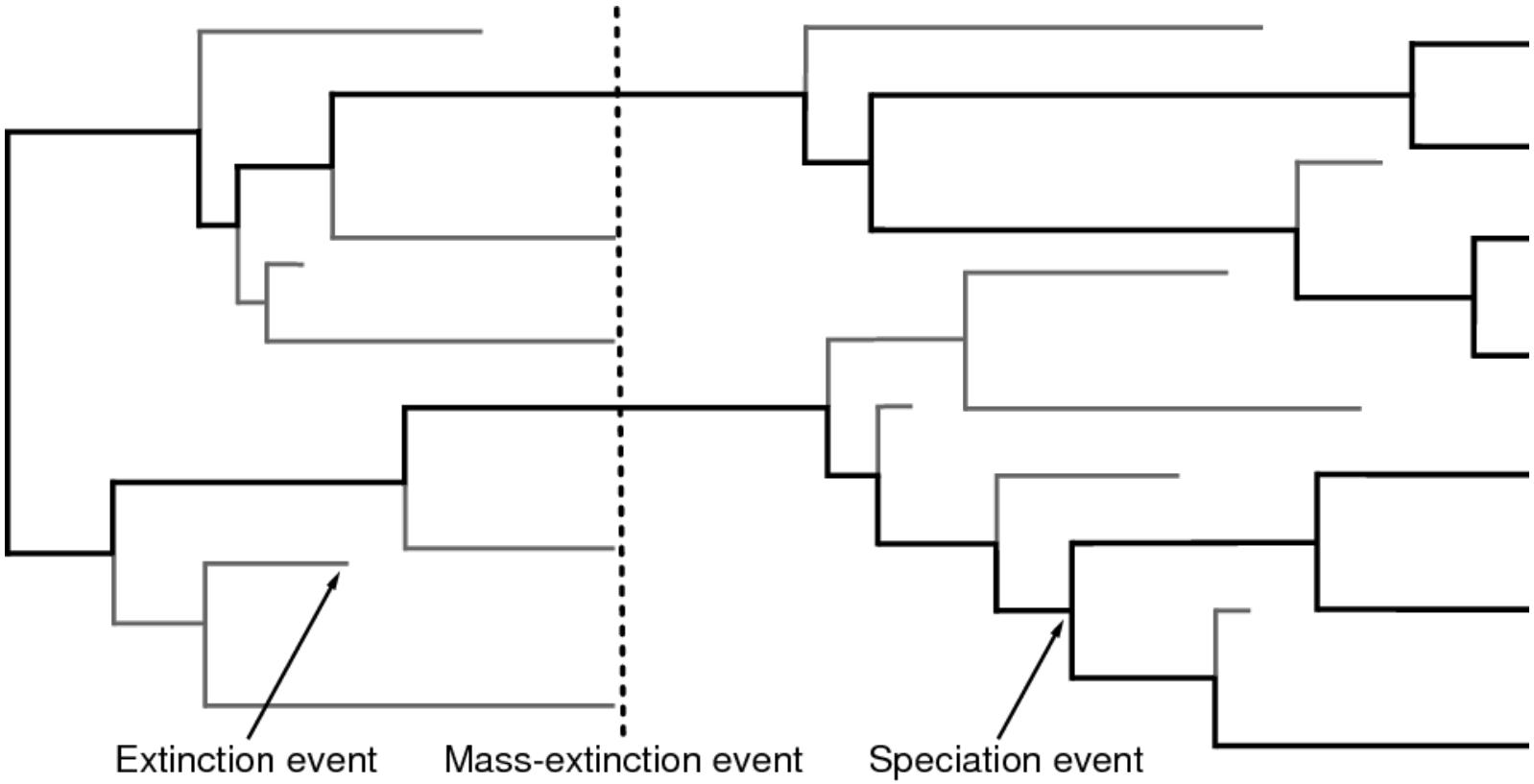
Definition: evolution at or above the species level

Also, long term trends, biases, or patterns in the evolution of higher taxonomic levels

Questions

- Is evolution gradual or punctuated (characterized by periods of stasis and large “jumps”)?
- What are the main drivers of macroevolutionary change?
  - intrinsic or extrinsic?
  - biotic or abiotic?
- Why are some clades more diverse than others?
- How do novel features evolve?

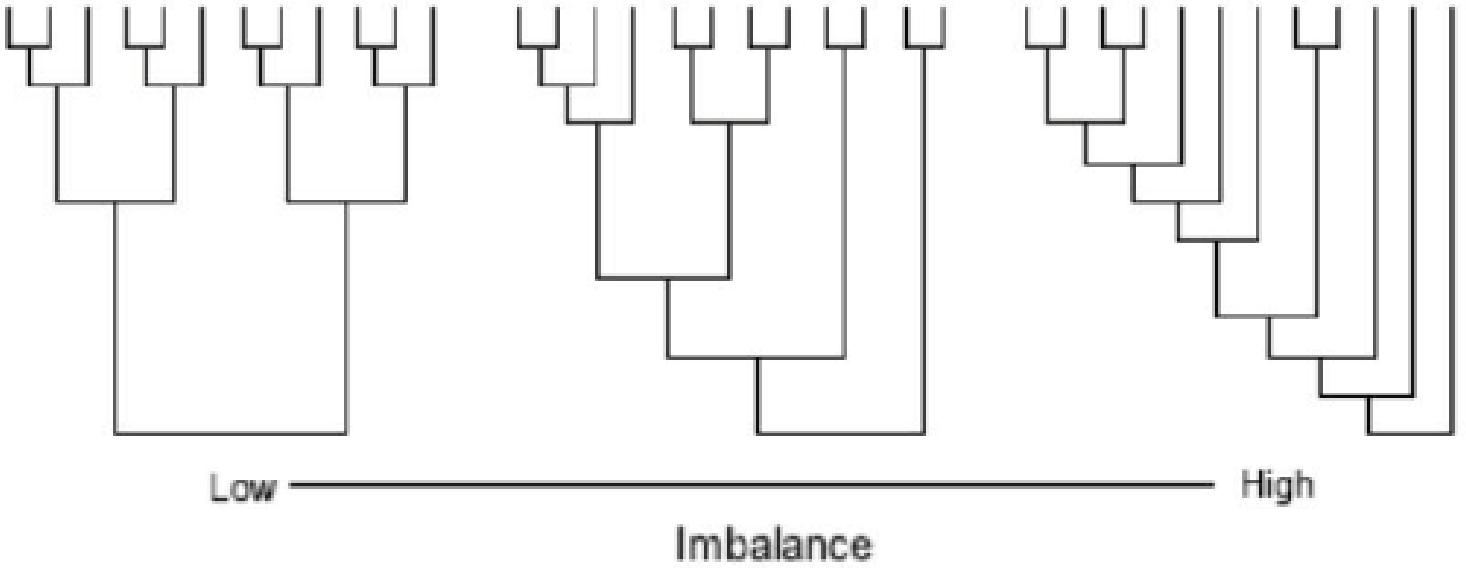
Diversity at the macroevolutionary scale

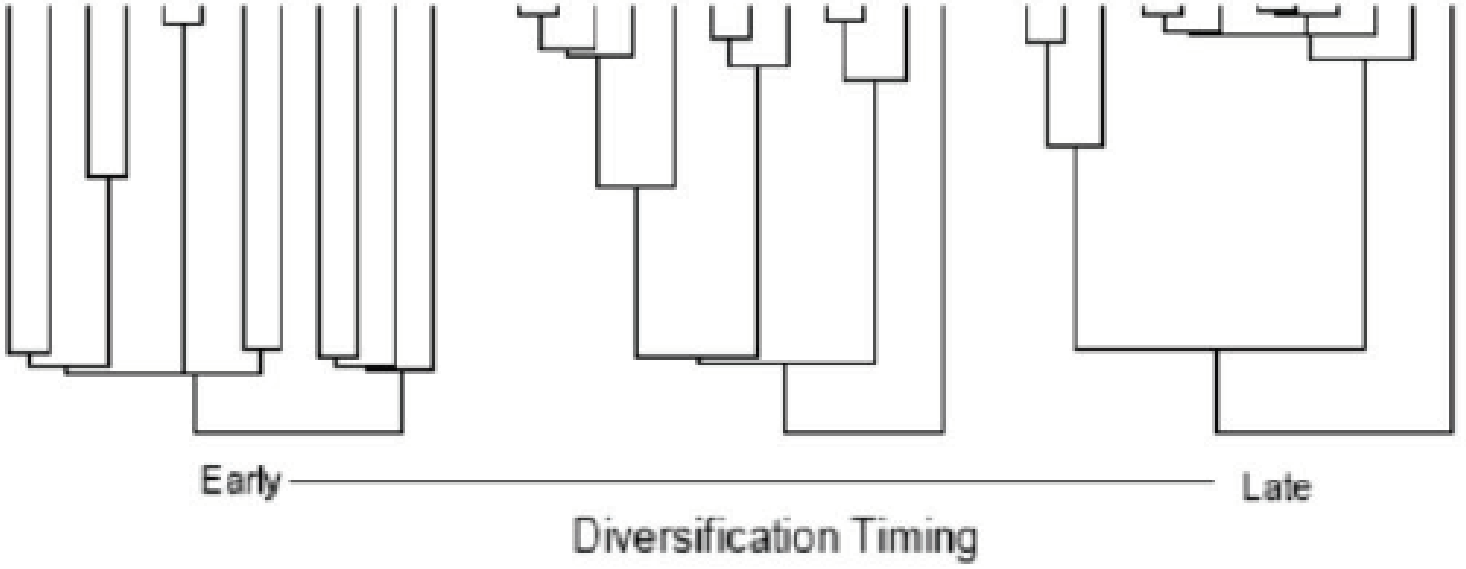


Net diversity = Number of speciation events – Number of extinction events

https://revbayes.github.io/tutorials/divrate/div_rate_intro.html

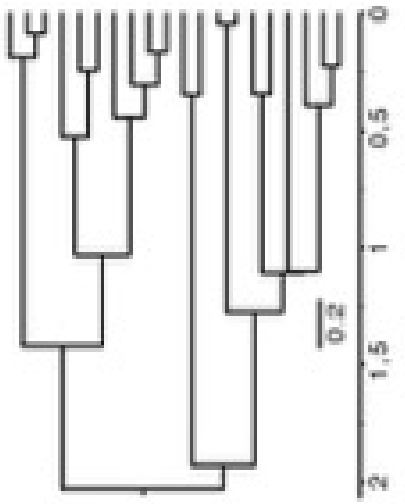
What can we learn from tree shape?



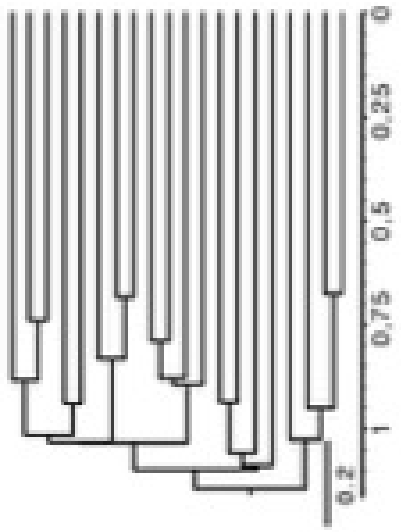


What can we learn from tree shape?

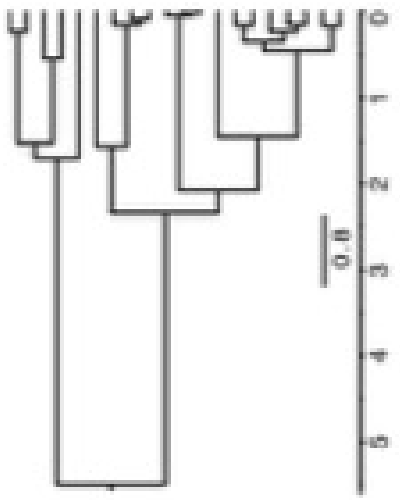
A = Constant speciation and extinction, half of lineages go extinct



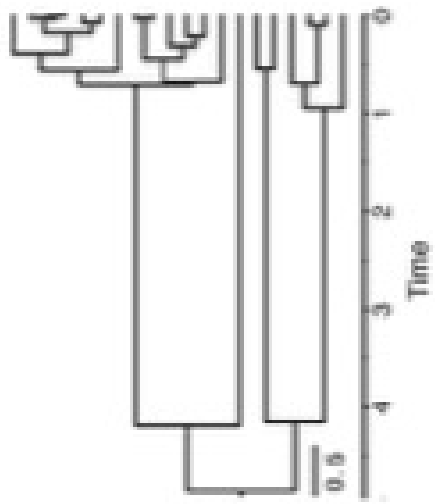
C = Early speciation and low extinction (near 0)



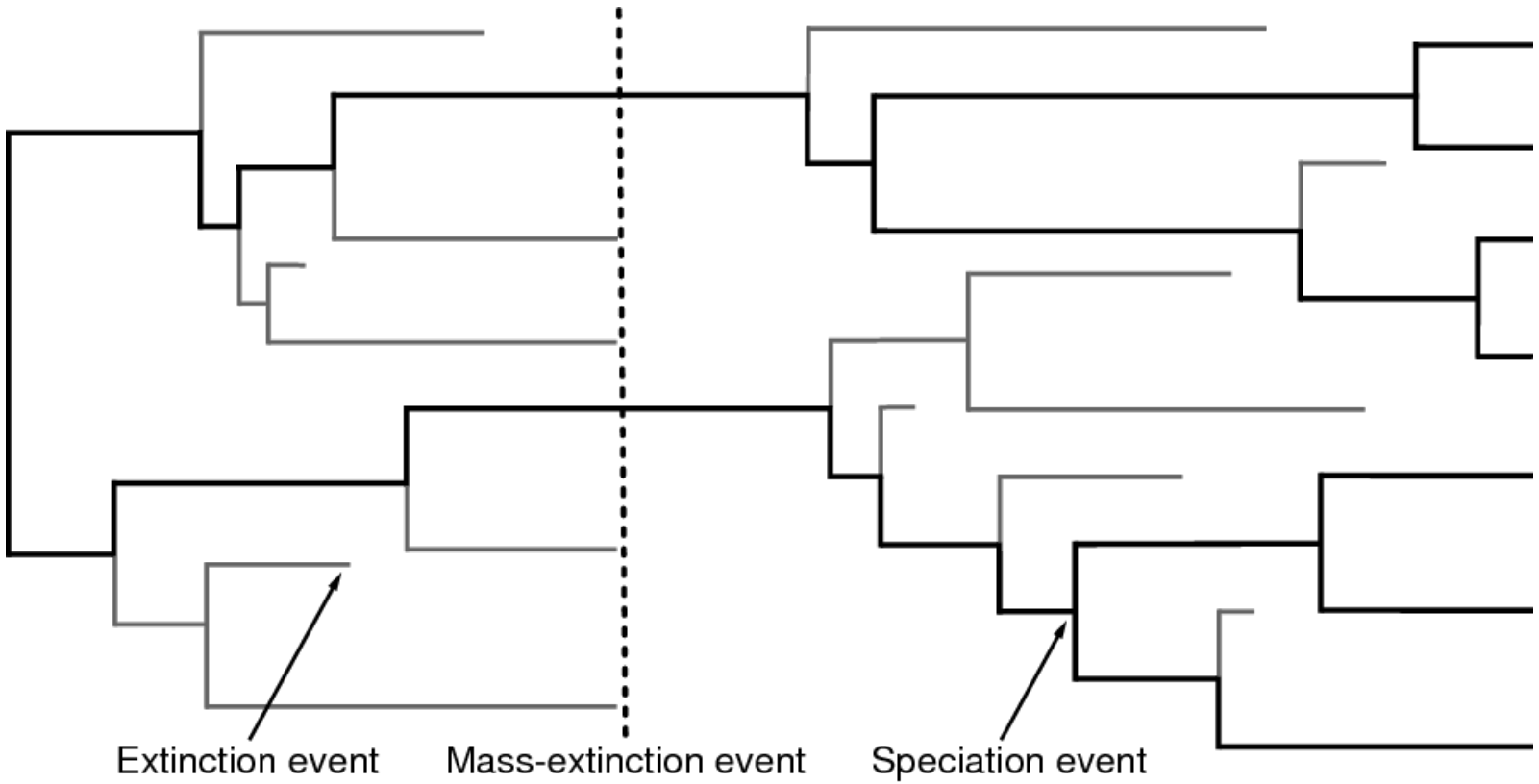
E = Extinction nearly as high as speciation



G = Massive extinction followed by speciation



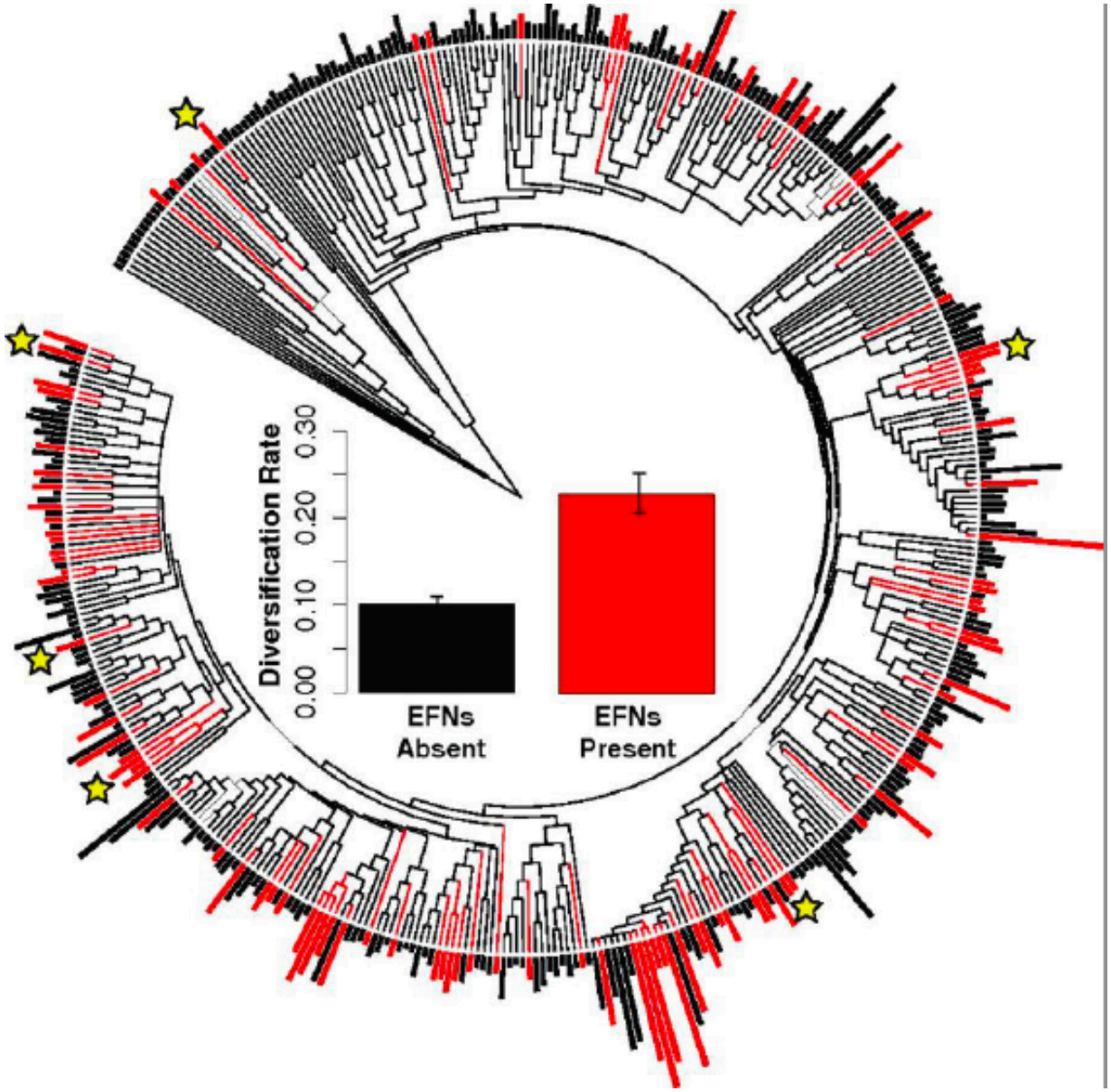
Diversity at the macroevolutionary scale



Net diversity = Number of speciation events – Number of extinction events

What affects rate of speciation and extinction?

Mutualism promotes diversification



Plant groups with extrafloral nectaries (AFNs) were more diverse than groups without them.

Weber and Agrawal 2014

What are the main extrinsic drivers of macroevolutionary change?

- Physical environment (abiotic)
- Interactions with other species (biotic)
- Darwin emphasized competition and predation
- Van Valen's Red Queen Hypothesis

Through the Looking Glass, Lewis Carroll

The Red Queen Hypothesis

- The continual evolutionary change by a species that is necessary to retain its place in an ecosystem because of ongoing interactions with other species. Food supplies, predators, competitors, pathogens, parasites, and intraspecific dynamics are constantly in flux.

- The targets of selection keep changing, and so the organisms is never perfectly adapted.

- Evidence for the Red Queen includes (from Benton 2009):

  – interspecific competition
  – character displacement
  – evolutionary arms races
  – incumbency advantage

The Court Jester

- An opposing model, the Court Jester, posits that stochastic changes to the physical environment(e.g., climate change, oceanographic or tectonic events) are the key drivers of major changes in organisms and diversity.

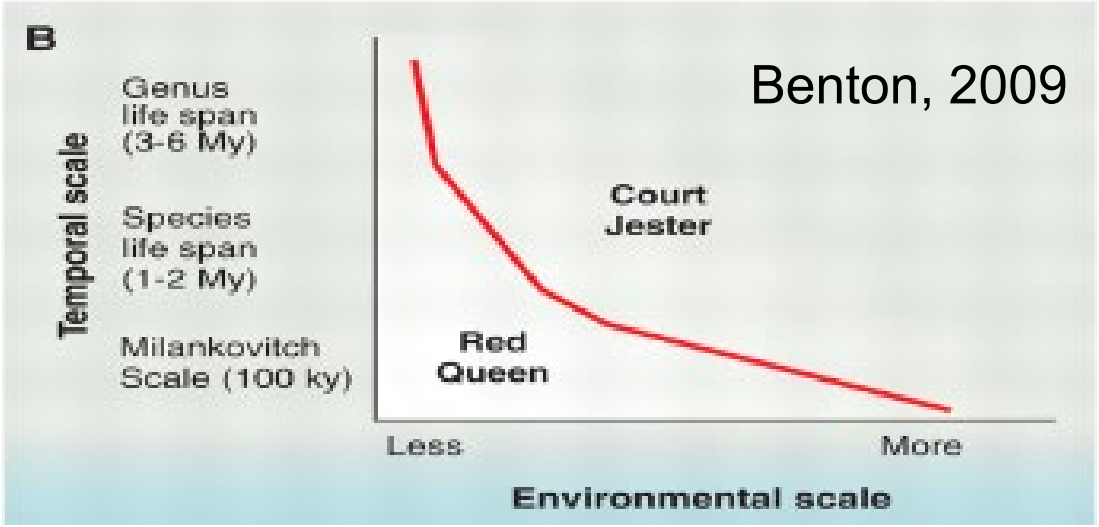
- Evidence for the Court Jester includes (from Benton 2009):
  - Mass extinctions (and minor extinctions) linked to stochastic abiotic events (e.g., eruptions, impact, anoxia)
  - Extinction probability is non-constant
  - Variation in diversification rates of clades correlated with tectonic and oceanographic events

- These two models are not mutually exclusive

Red Queen versus Court Jester

Barnosky (2001) suggests that the two different models may operate on different spatial & temporal scales

– Red Queen works best for short-term, ecosystem-scale processes, but these local patterns may be overwhelmed at larger scales where ‘random geological events’ have large effects



Lineage diversity

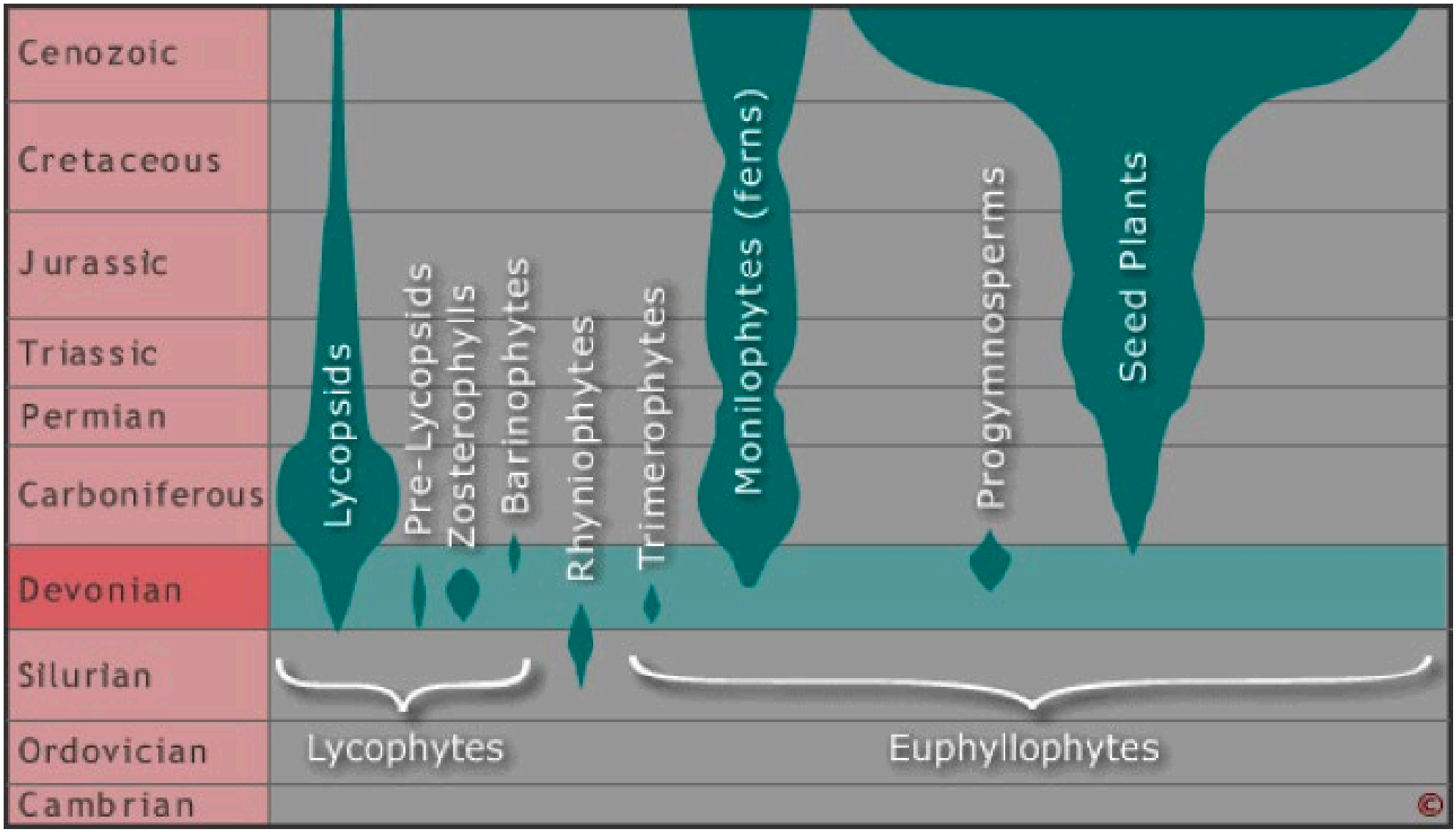
Observation:

There are some particularly diverse, species-rich clades

AND

There are some species-poor clades

Why are some clades more diverse?



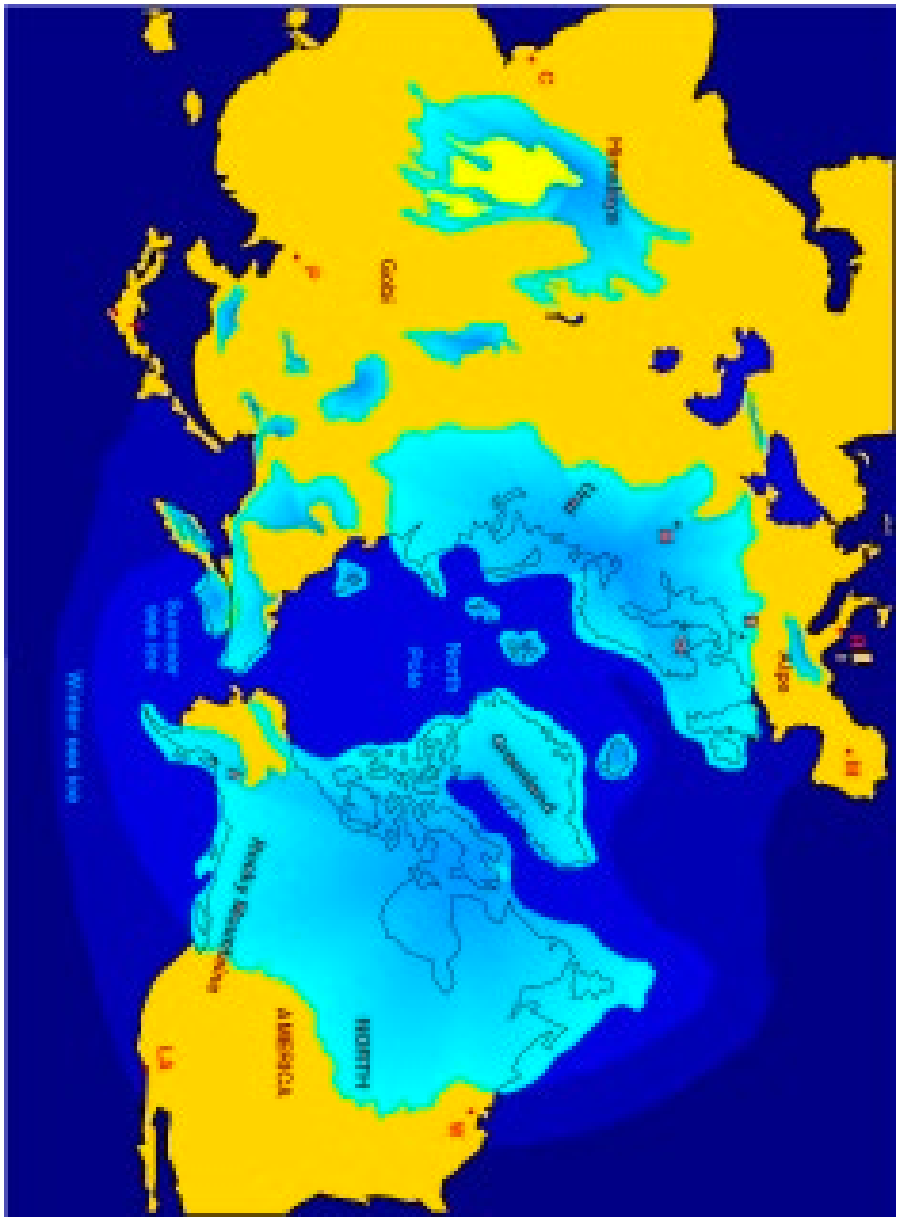
Why are some clades more diverse?

Three main reasons

Stochasticity: If speciation is random, then clades with more species are more likely to speciate than clades with fewer species.

Extrinsic Factors: external factors such as competition, climate and geology, can affect speciation and extinction rates.

Intrinsic Factors: a single trait, or combinations of traits, can affect a clade's speciation and extinction rates.



Adaptive Radiation

Definition: the evolution of ecological diversity in rapidly multiplying lineages

George G. Simpson (famous paleontologist and one of the founders of of the modern evolutional synthesis) first described the term.

Adaptive radiations results from **diversification accelerated by ecological opportunity**

- new environment
- extinction of competitors
- new way of life (key innovations)

Identifying Adaptive Radiations

Criteria from Schluter (2000):

1. Single common ancestor of component species

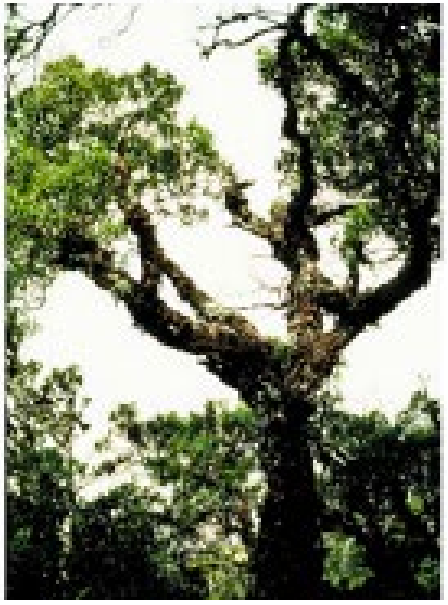
2. Increase in speciation rate

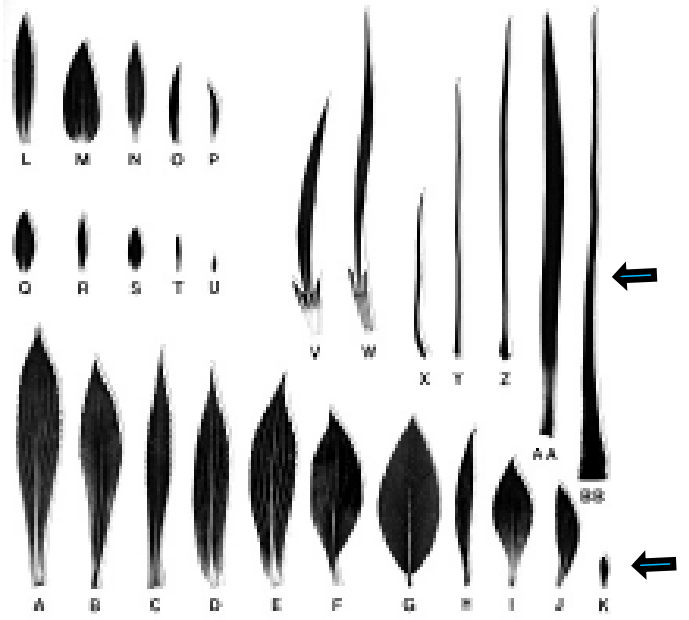
3. Associated increase in ecological and phenotypic diversity

   – phenotypes must be correlated with environments and increase fitness in “home” environment

Hawaiian silversword alliance

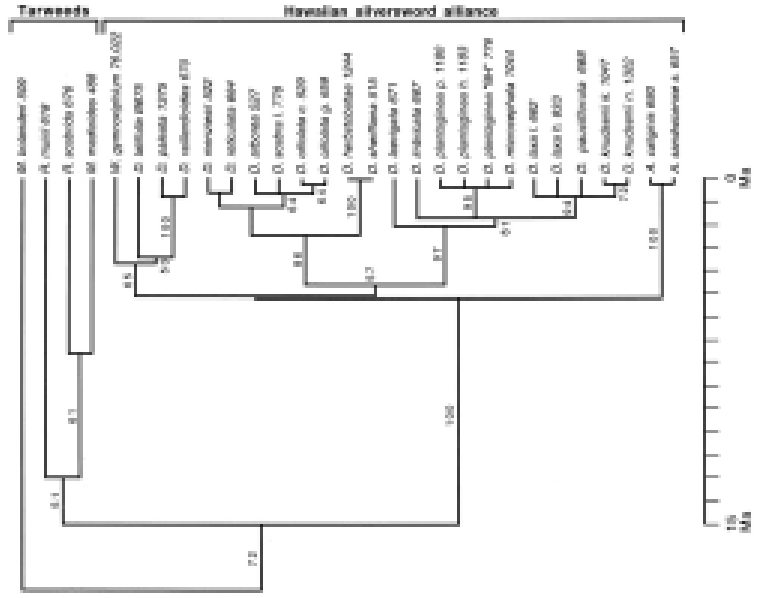
"the greatest living example of adaptive radiation in plants" Schluter, 2000





Dry & open habitat

Wet & shady

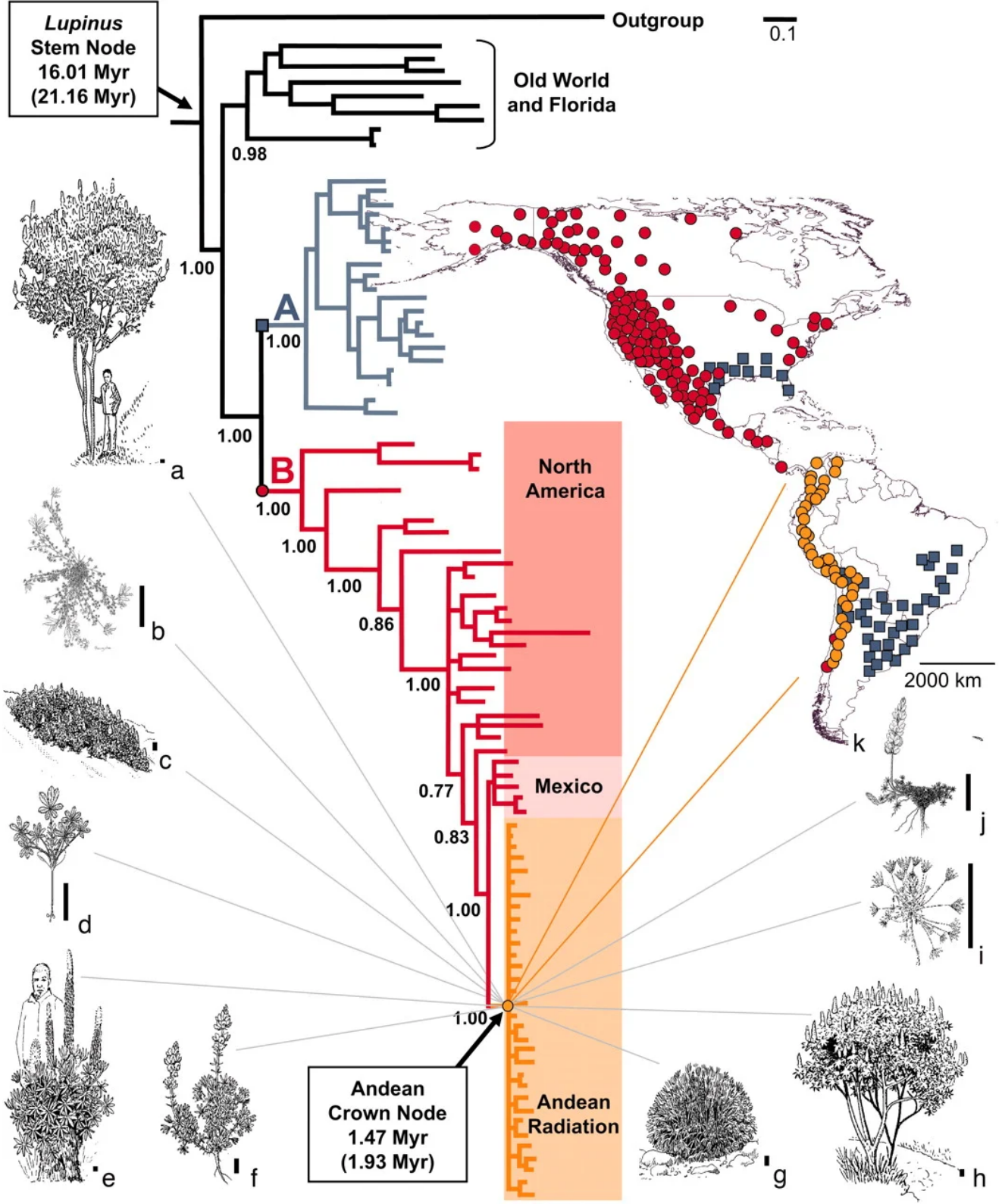


Andean Lupinus

Andean Uplift took place 2-4 million years ago, which created ecological opportunities for diversification. In the case of *Lupinus*, > 80 species were formed in 1-2 million years.

Phylogeny of *Luplinus* showing exceptional rate of diversification after uplift of Andes

(Hughes & Eastwood, 2006)



(Non-)adaptive radiations

Criteria from Schluter (2002):

1) Common ancestor of component species;

2) Increase in speciation rate;

~~3) Associated increase in ecological and phenotypic diversity.~~

Non-adaptive radiation:
rapid speciation in the absence of ecological diversification

e.g., Aegean Nigella arvensis complex

– 12 taxa

– similar habitats on different islands

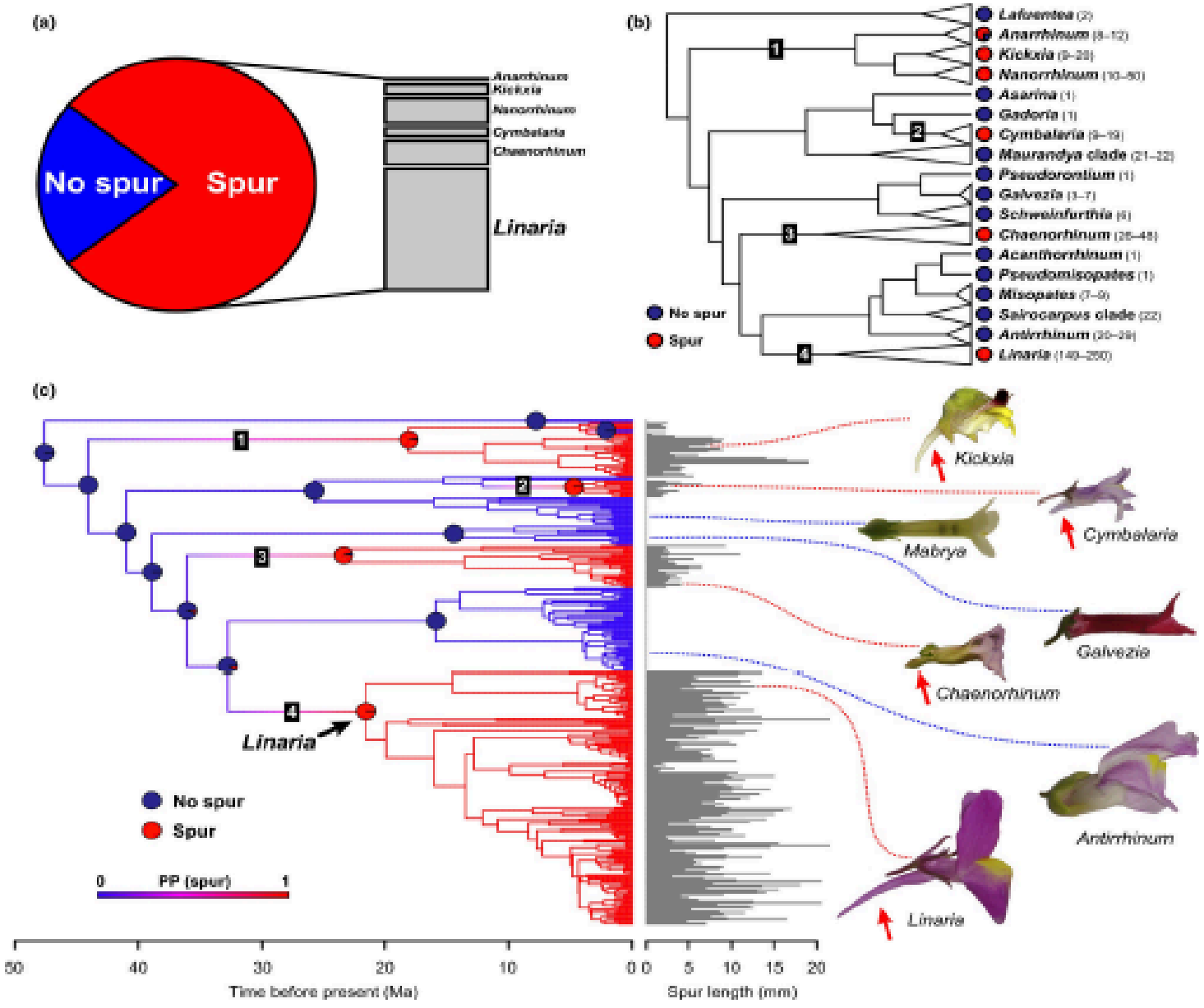
– changes in sea level allow dispersal, selfing

So, what likely drove this radiation?

Instrinsic Factors – Key Innovations

Key innovations are novel traits thought to open new ‘adaptive zones’ (the ability to exploit new niches) or to increase diversification rates by decreasing extinction rates and/or increasing speciation rates.

Macroevolutionary dynamics of nectar spurs of Antirrhineae, a key evolutionary innovation



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Unanswered Questions

1. Is evolution gradual or punctuated?
2. Is evolution primarily driven by biotic or abiotic factors?
3. Is evolution repeatable?

   – “replaying tape of life”