Speciation mechanisms



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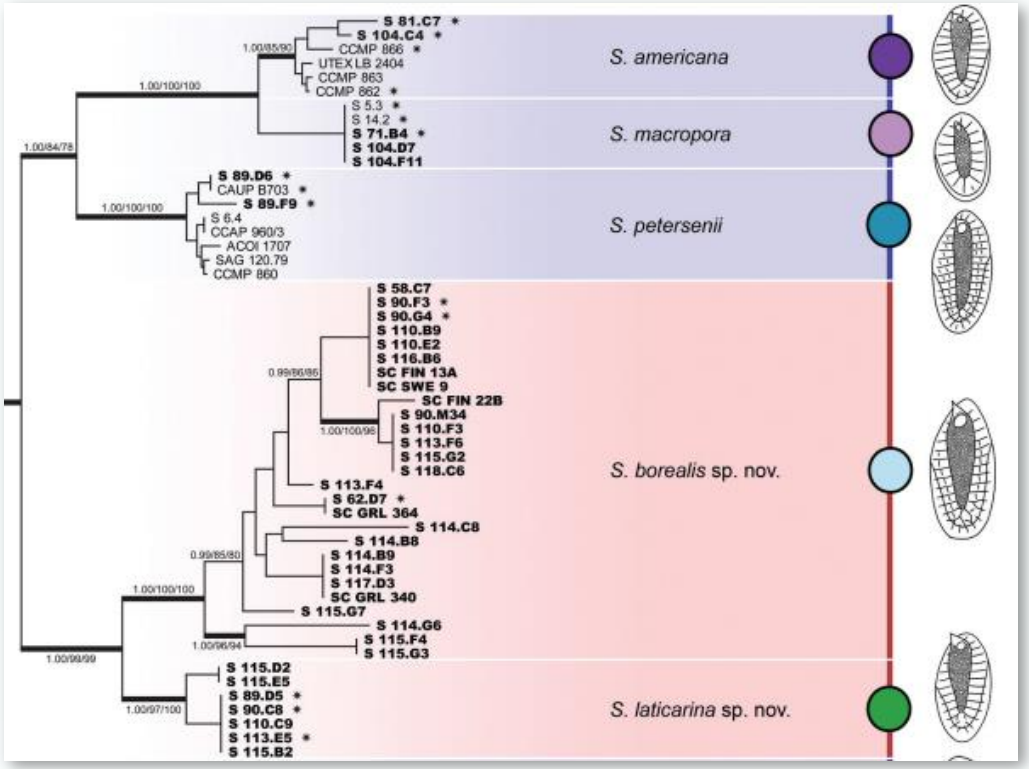
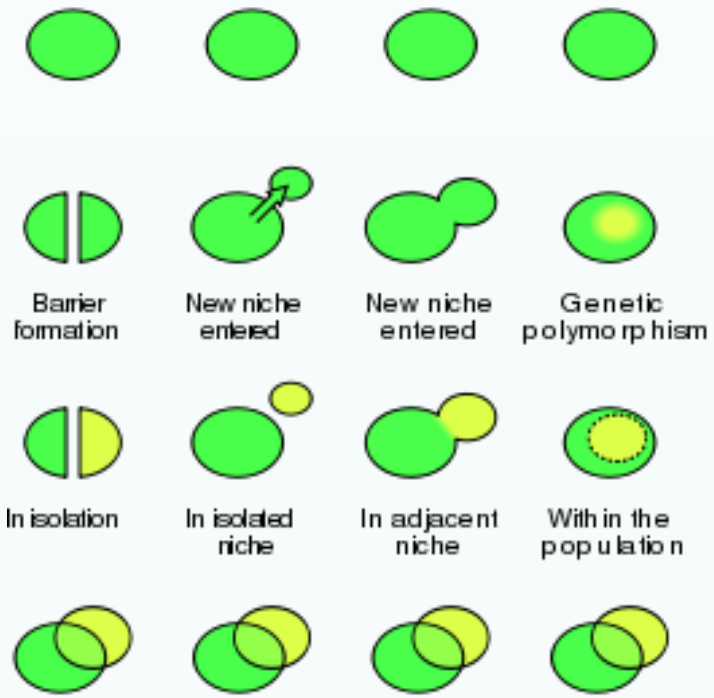
Species concepts

- What are the general causes of protist speciation?

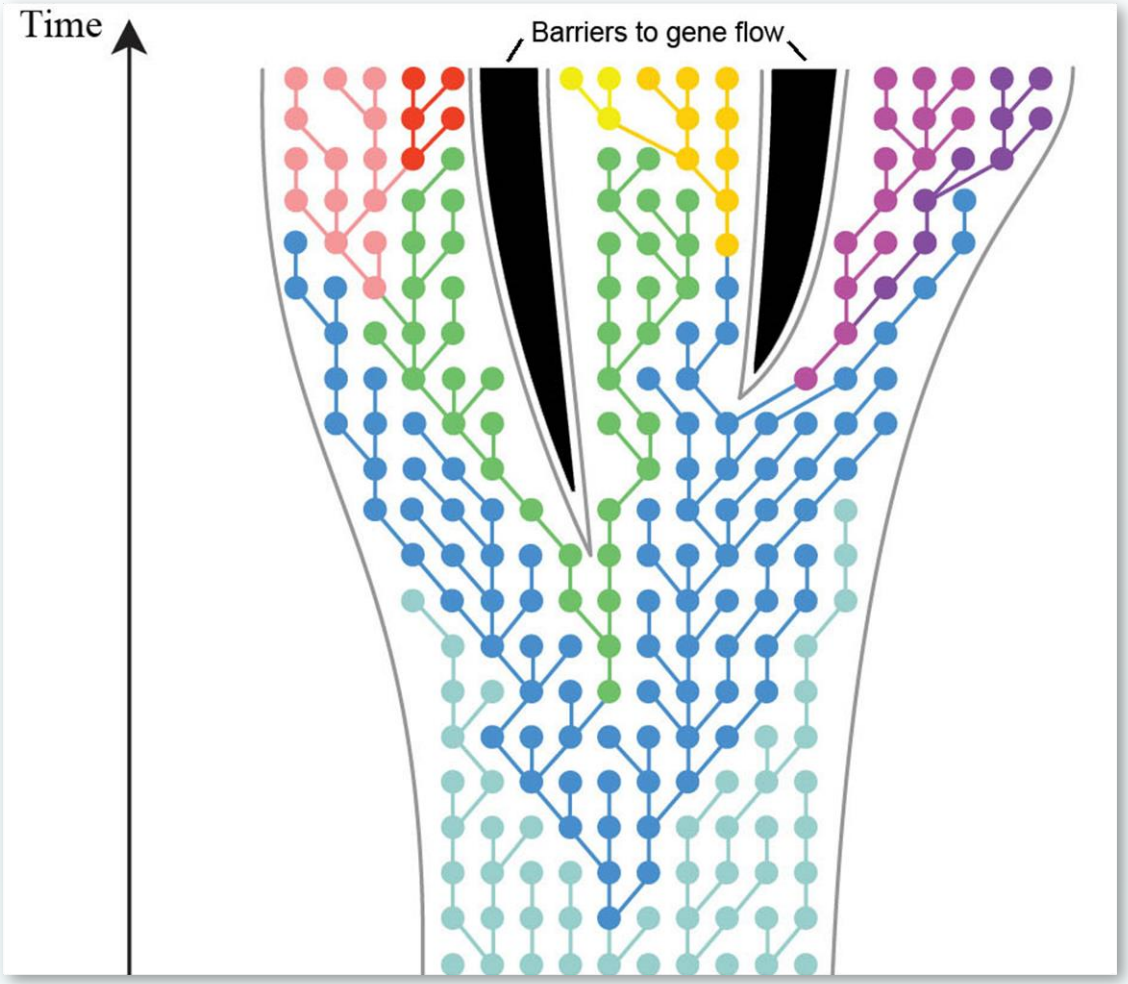
1. Allopatric / sympatric speciation models
2. Speciation mechanisms in microalgae
3. Speciation models

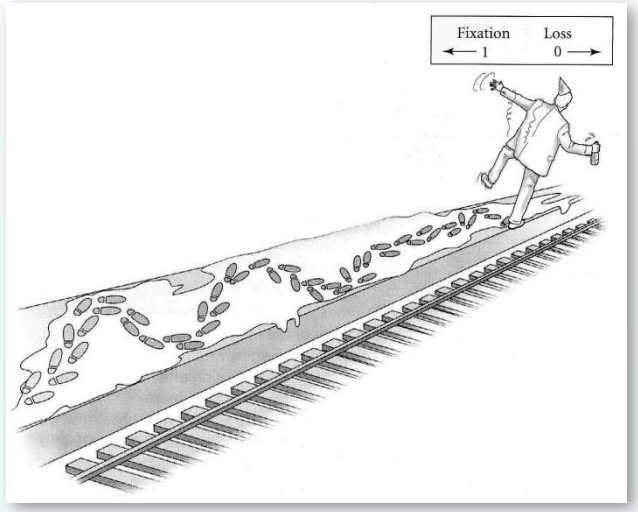


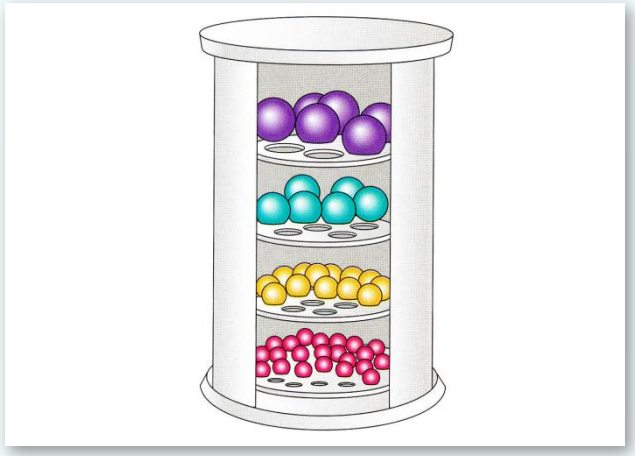


Models of speciation

- Species = populations with distinguishing characteristics
- Barriers to gene flow as a key factor in speciation

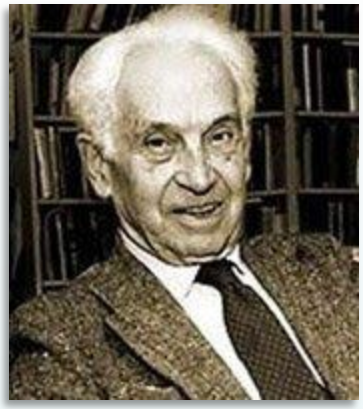




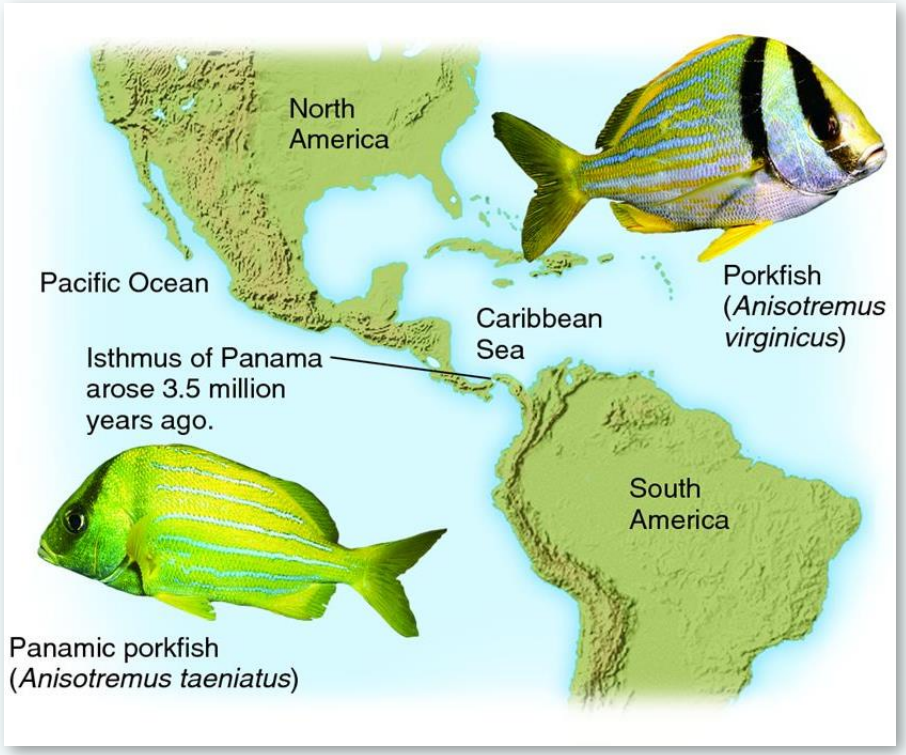


Leliaert et al. (2014). *Eur. J. Phycol.* **49**: 179-196

Models of speciation



- **Allopatric speciation** = geographical barrier to gene flow
- Ernst Mayr (1946): "*differentiation of populations must be preceded by geographical or other means of physical isolations*"

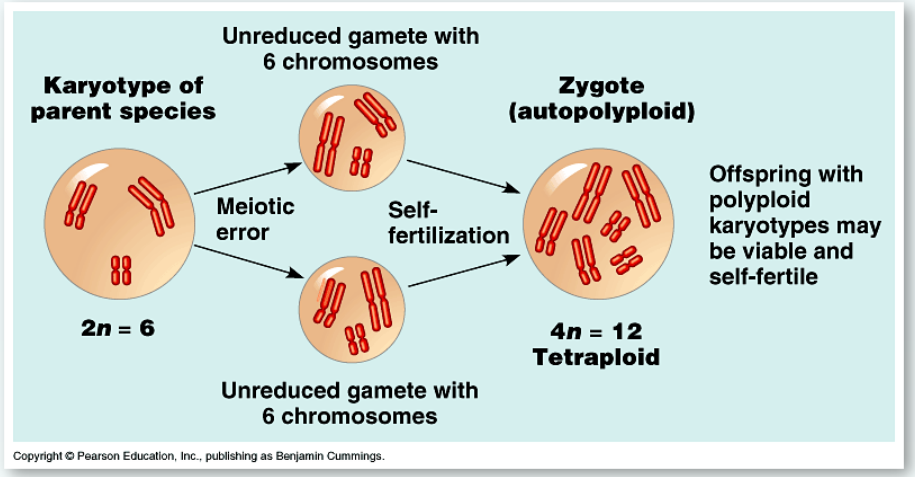


Knowlton et al. (1993). *Science* **260**: 1629-1632

Models of speciation

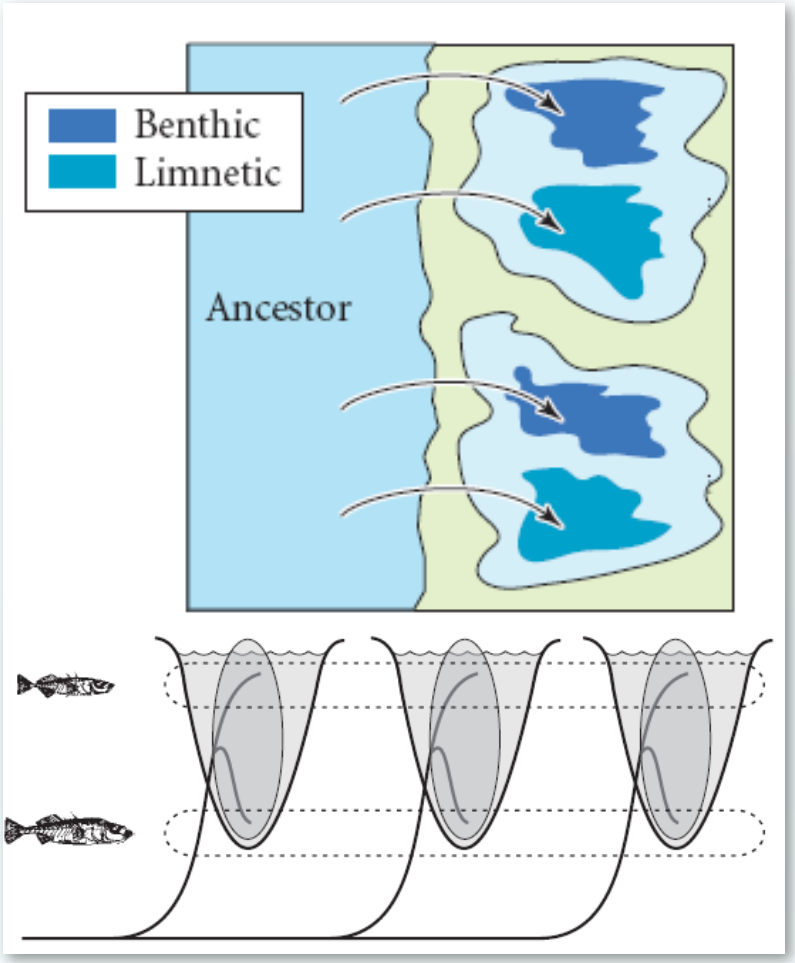
- **Sympatric ecological speciation** = barrier to gene flow as a result of ecologically-based divergent selection

- Ecological factors of speciation:
  - Habitat isolation (salinity levels, substrate types, host species ...)
  - Temporal isolation (flowering times)
  - Sexual isolation (selection for body size)
  - Gametic isolation (gamete recognition mechanisms)
  - Postzygotic isolation (hybrid low fitness / lethality)
  - Cytological isolation (polyploidisation)



Models of speciation

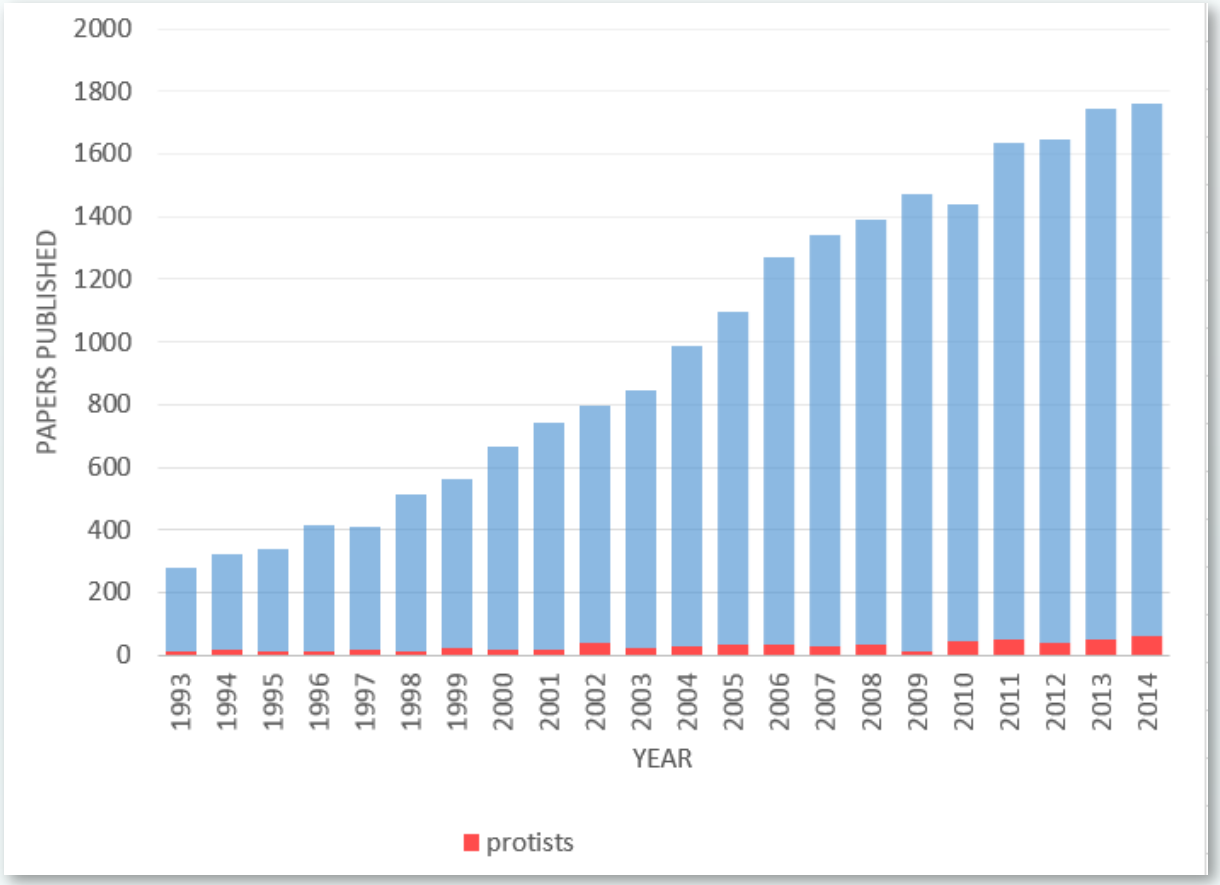
- Parallel speciation of three-spined stickleback in Canadian lakes
  - Limnetic species = open-water, larger form
  - Benthic species = bottom/feeding, smaller form



Rundle et al. (2000). *Science* **287**: 306-308

Speciation in microalgae

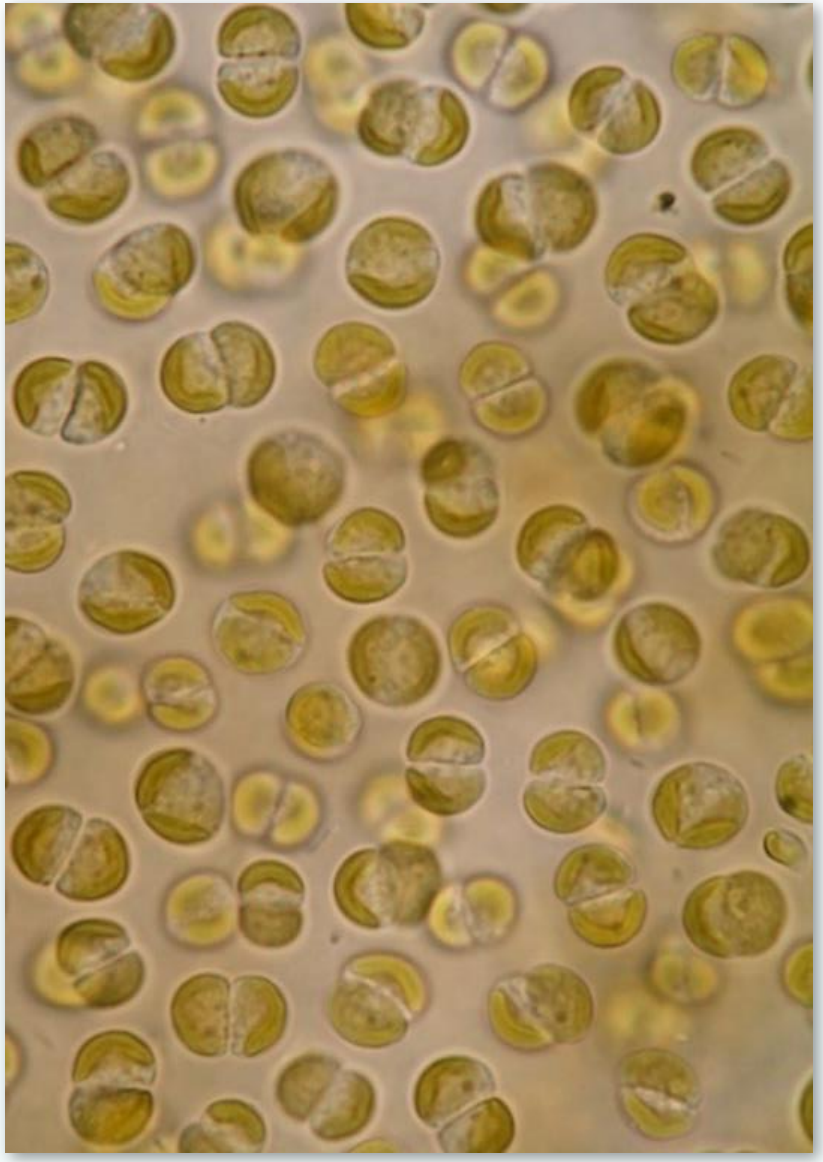
- Only a very small fraction of papers focusing on speciation is dealing with eukaryotic microorganisms.
- Thought protists are extremely numerous and essential in global ecosystem functioning, our knowledge of their speciation is vastly limited.



Web of Science literature search for papers of the topic "speciation" for the years 1993–2014, refined to subject areas "evolutionary biology," "ecology," or "genetics and heredity." Papers refined to topic "algae", "protist" or "protozoa" are given in orange.

Specificity of protist organisms

- Short generation time
- Enormous population sizes
- Unlimited dispersal & gene flow



Unlike the macroorganisms:

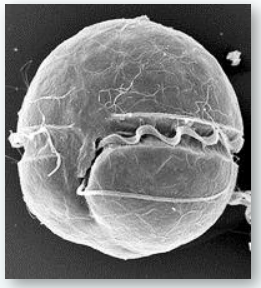
- Ubiquitous distribution
- Absence of population differentiation
- Barriers to gene flow extremely rare
- Very low speciation rate

How do the protists speciate?

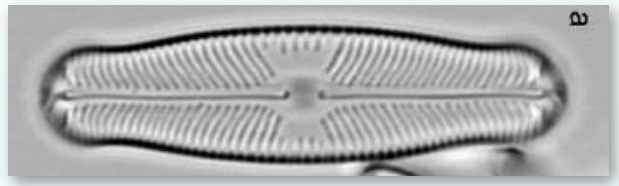
Finlay & Fenchel (1999). *Protist* **150**: 229-233

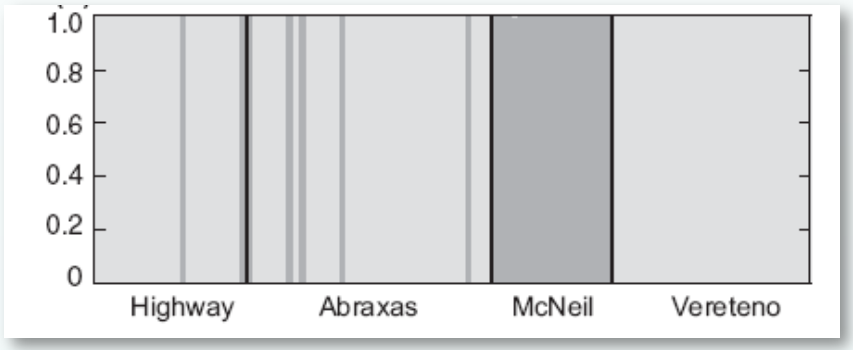
Genetic structure of protist populations

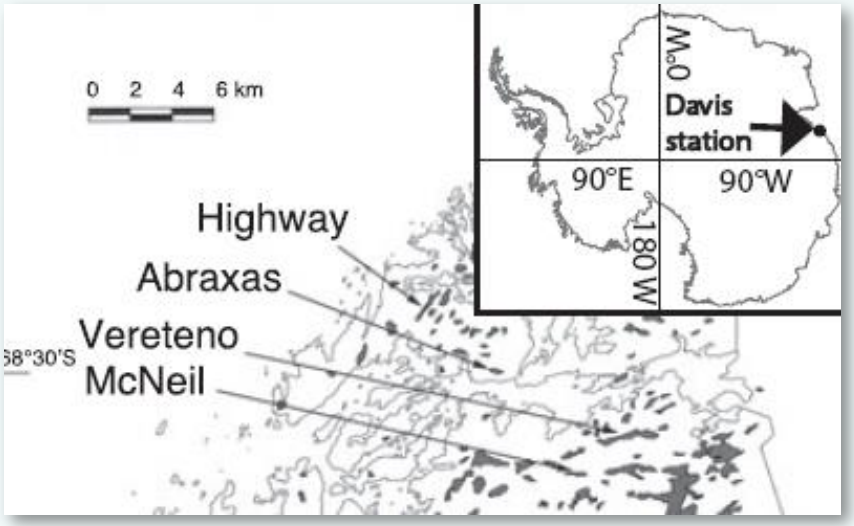
- *Scrippsiella hangoei*

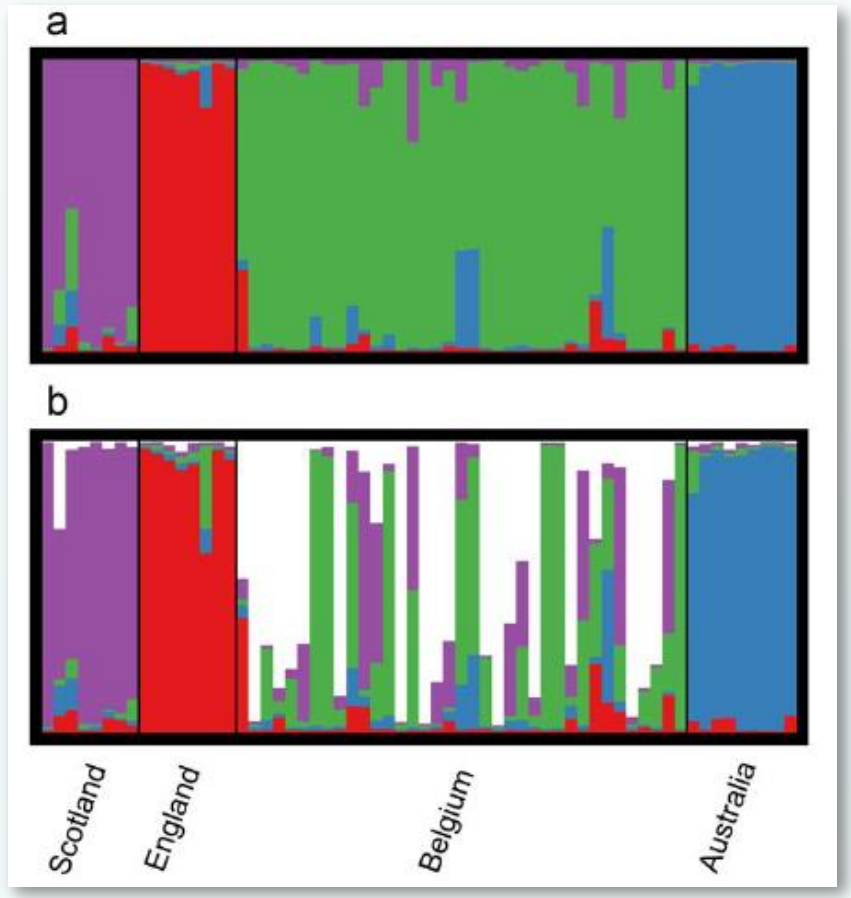


- *Sellaphora capitata*









Rengefors et al. (2012). *Mol Ecol* **21**: 3200–3209

Evans et al. (2009). *Protist* **160**: 386–396

Mechanisms of protist speciation

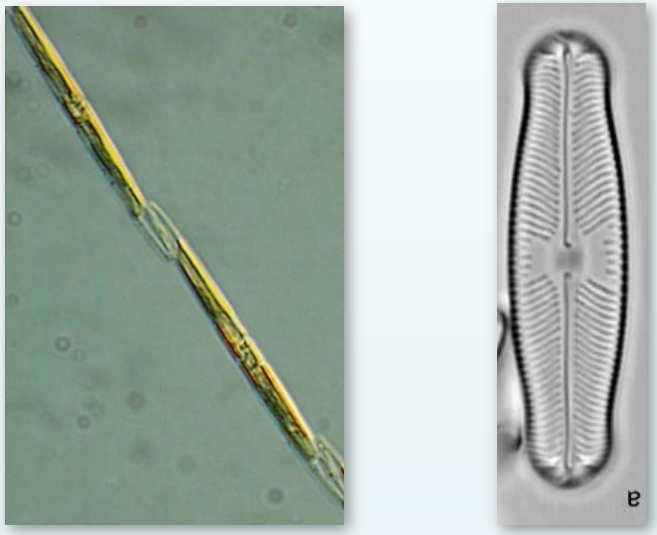
Genetic differentiation of protist species into distinct populations

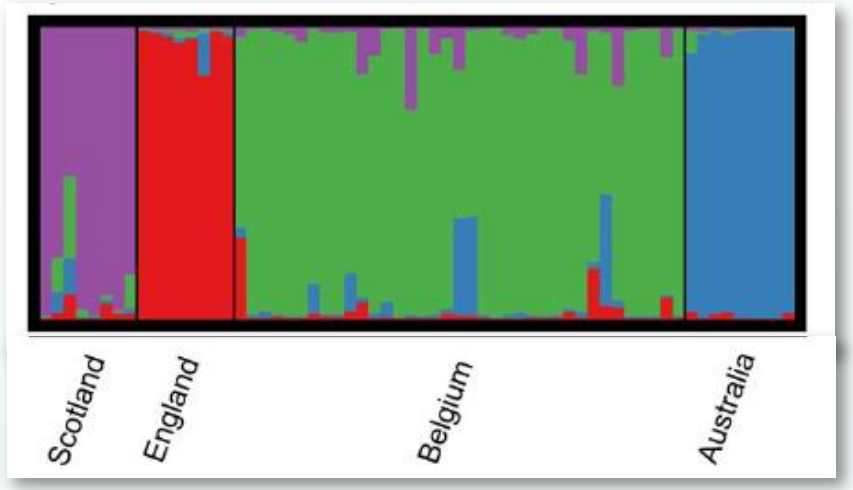
Mechanisms of gene flow restriction?

Mechanisms of protist speciation

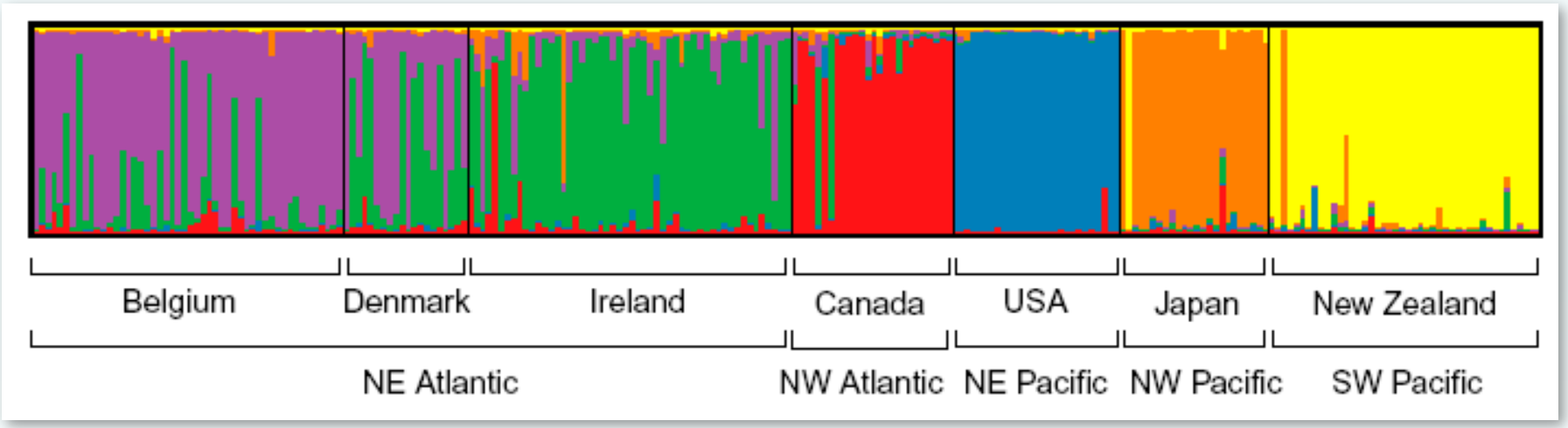
1. Geographic isolation

Evans et al. (2009). *Protist* **160**: 386–396





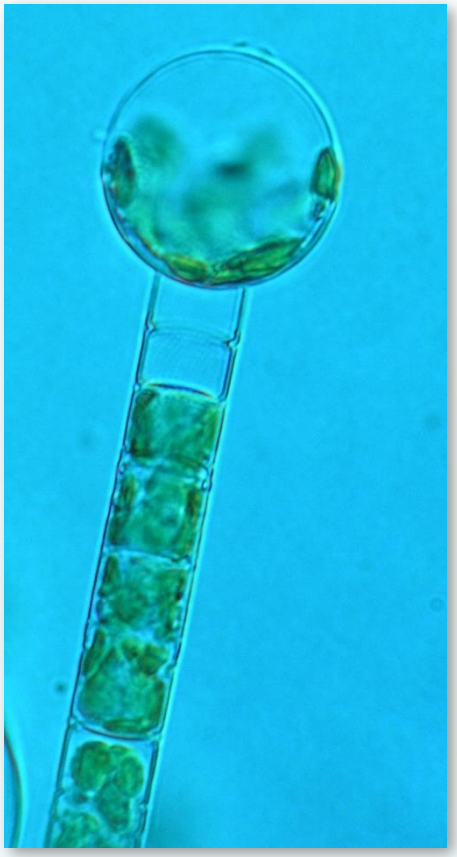
Casteleyn et al. (2010). *PNAS* **107**: 12952-7

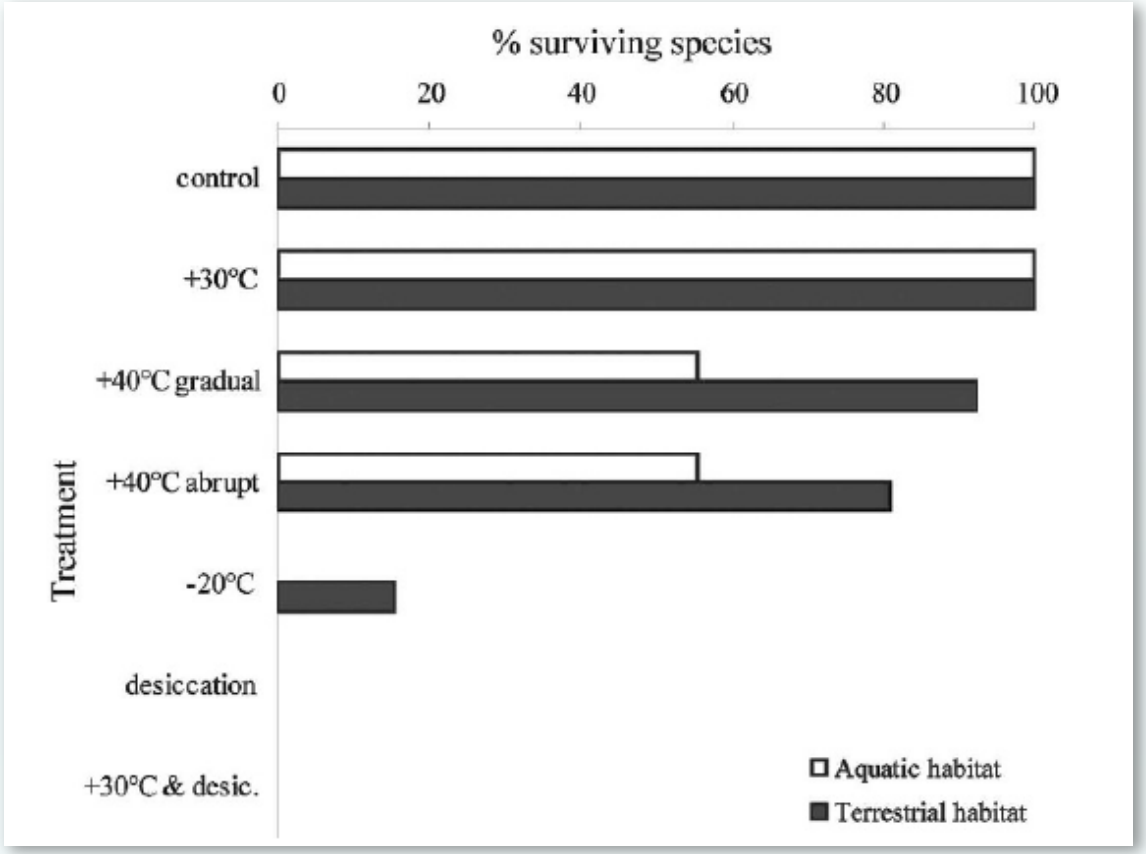


Mechanisms of protist speciation

1. Geographic isolation

- Freshwater and terrestrial diatoms = the absence of dessication-resistant cysts can cause the limited dispersal.



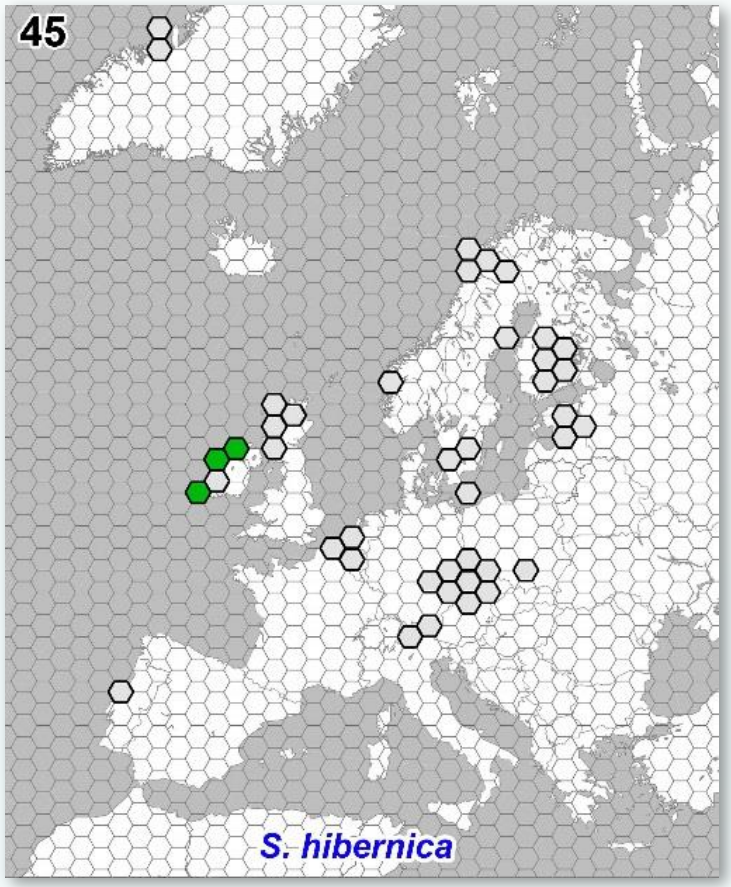


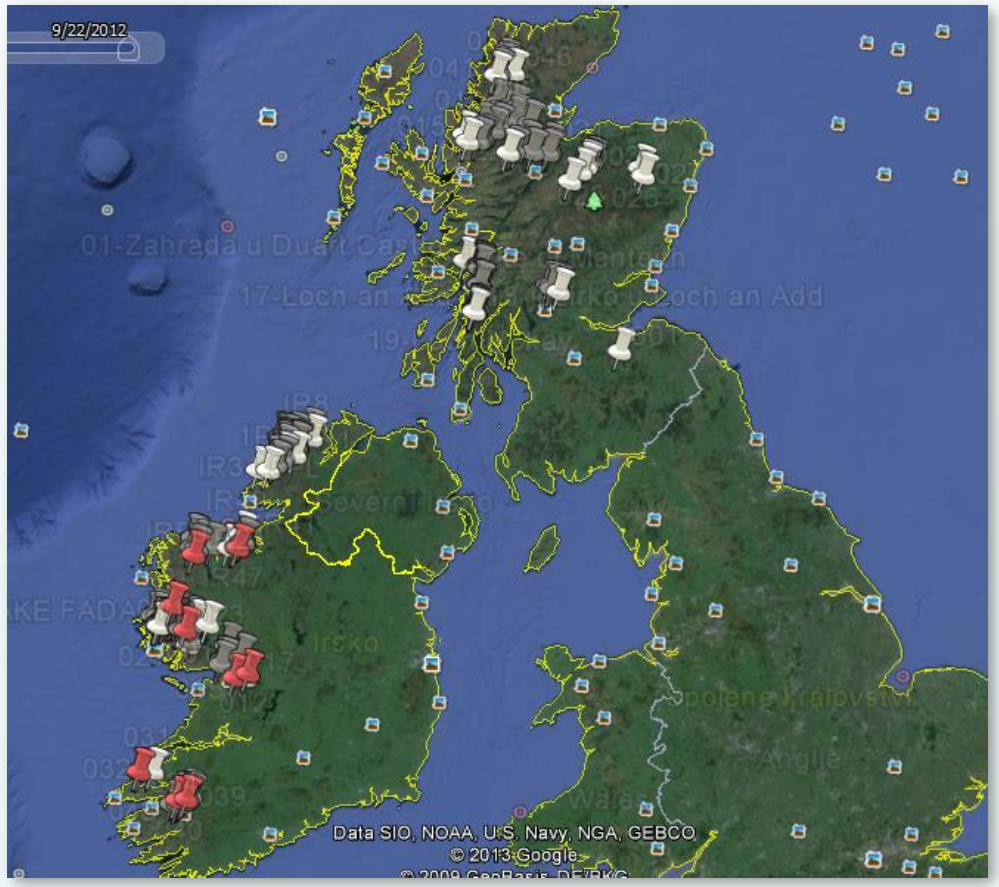
Souffreau et al. (2010). *Phycologia* **49**: 309-324

Mechanisms of protist speciation

1. Geographic isolation

- *Synura hibernica* – restricted to western Ireland



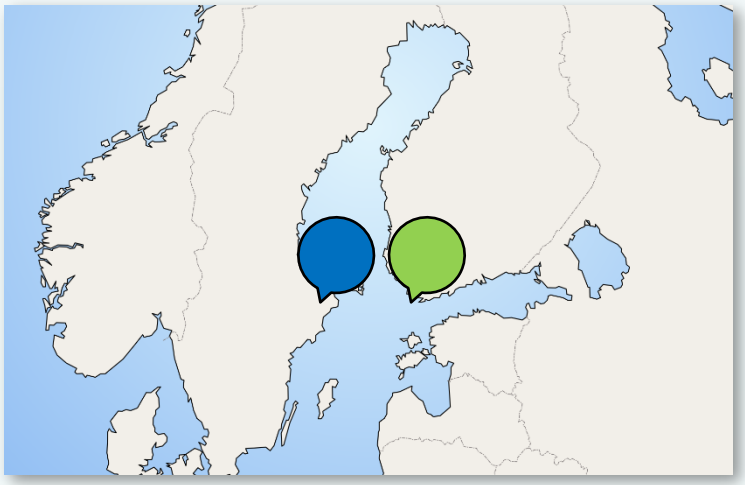


Škaloud, Škaloudová, Procházková & Němcová (2014). *Eur. J. Phycol.* **49**: 213-229

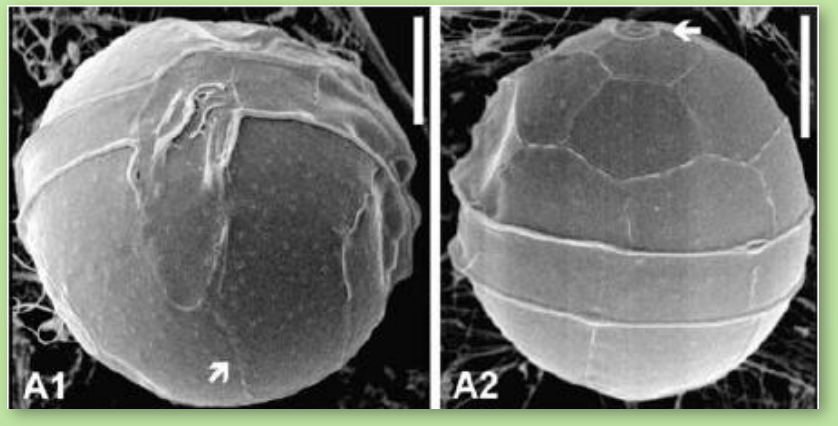
Mechanisms of protist speciation

2. Ecological isolation

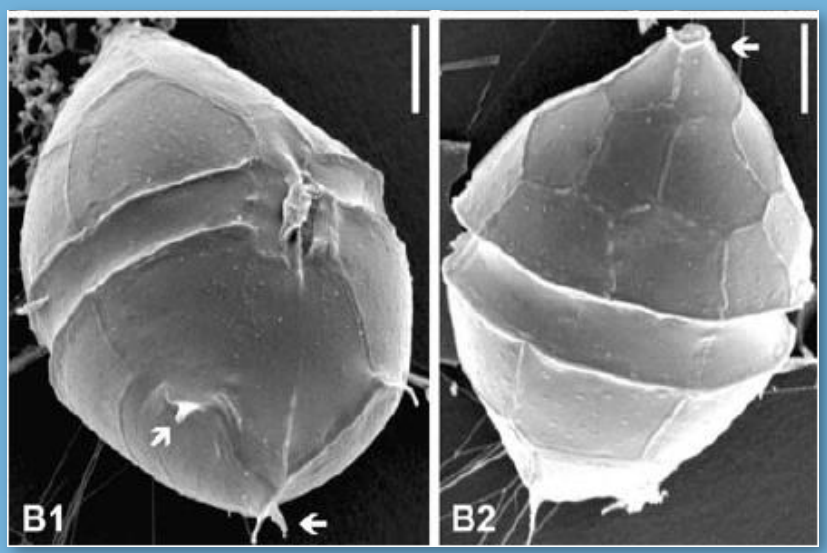
- Recent marine-freshwater transition of a dinoflagellate accompanied with a significant morphological differentiation
- Identical ITS and SSU rDNA
- Probably a rapid postglacial disruptive ecological selection (~ 10,000 years BP)



Scrippsiella hangoei - brackish



Peridinium aciculiferum - freshwater

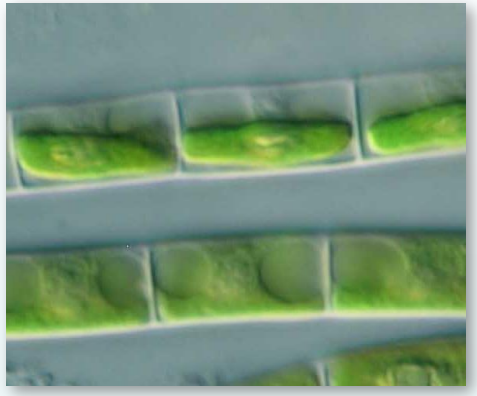


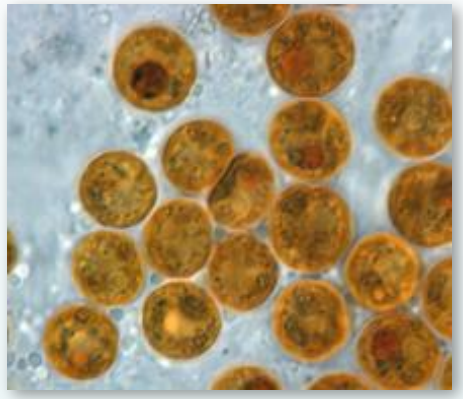
Logares et al. (2007). *Microb. Ecol.* **53**: 549-561

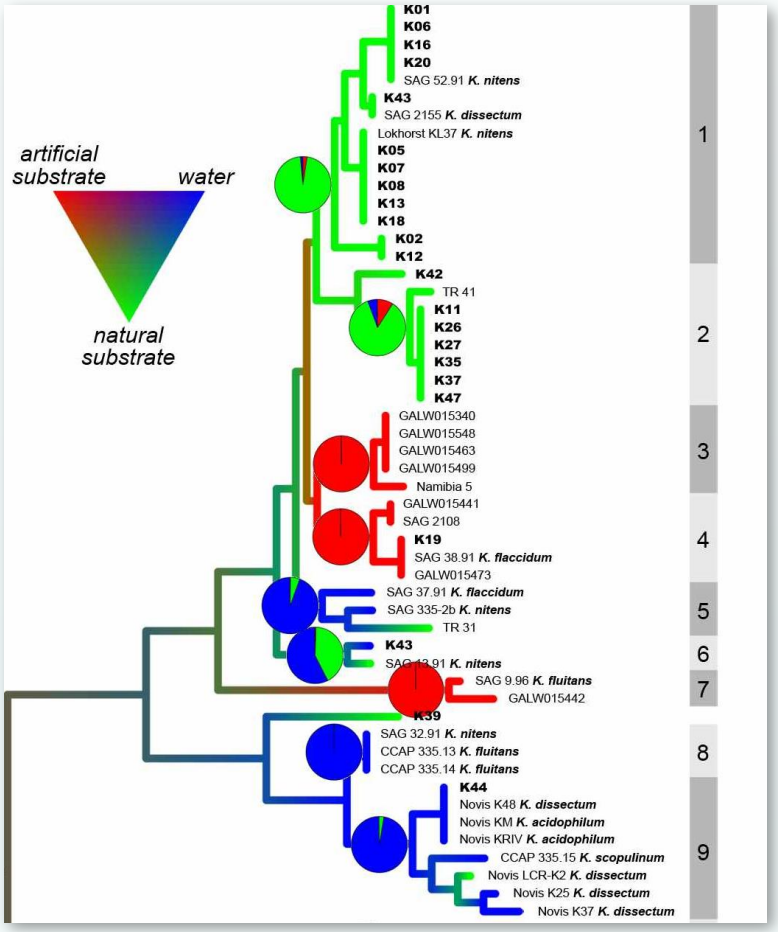
Mechanisms of protist speciation

2. Ecological isolation

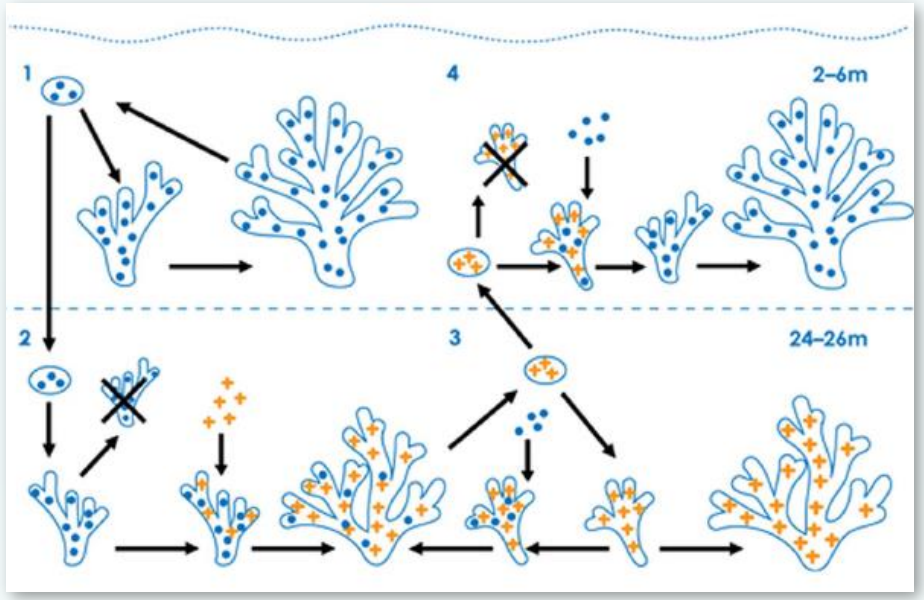
- *Klebsormidium*







- *Symbiodinium*



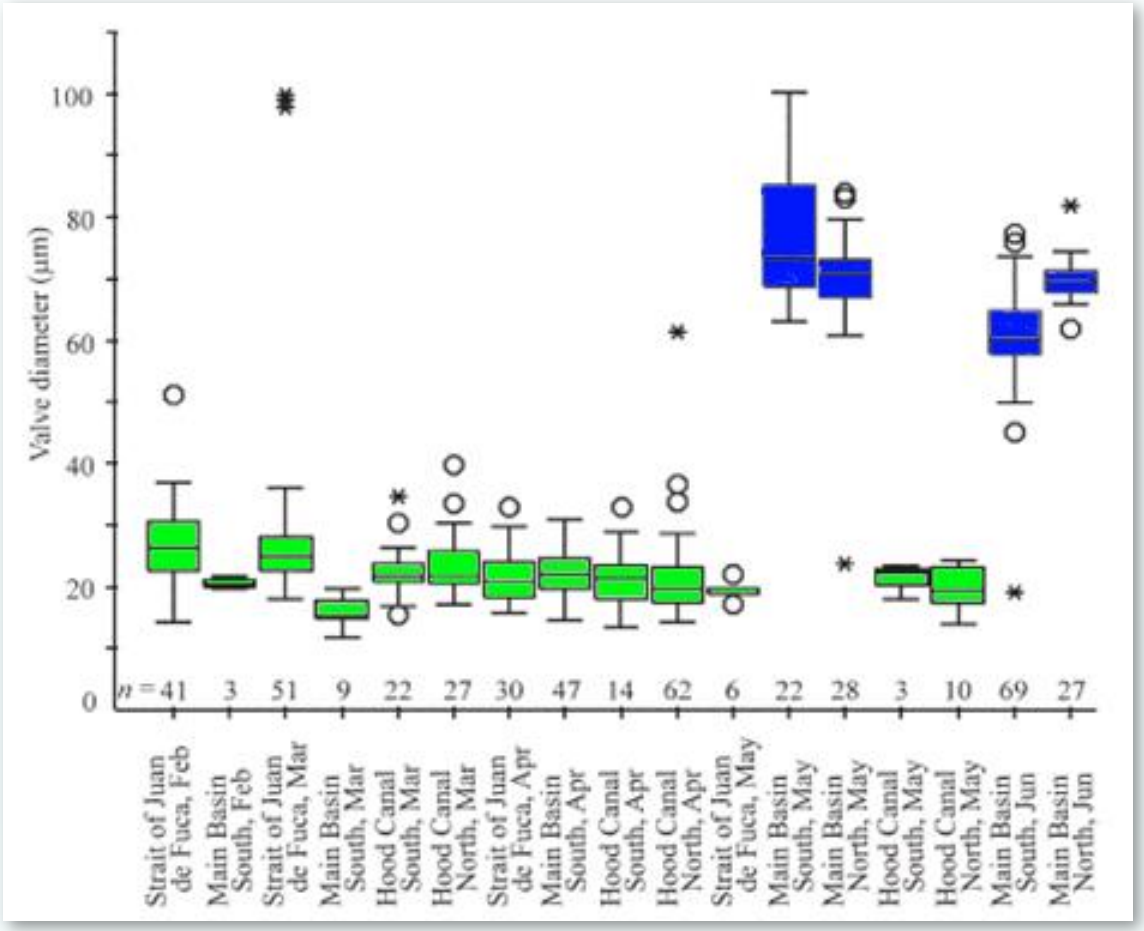
Škaloud & Rindi (2013). *J. Euk. Microbiol.* **60**: 350-362

Byler et al. (2013). *Plos ONE* **8**: e59596.

Mechanisms of protist speciation

3. Temporal isolation

- Population of *Ditylum brighwellii*

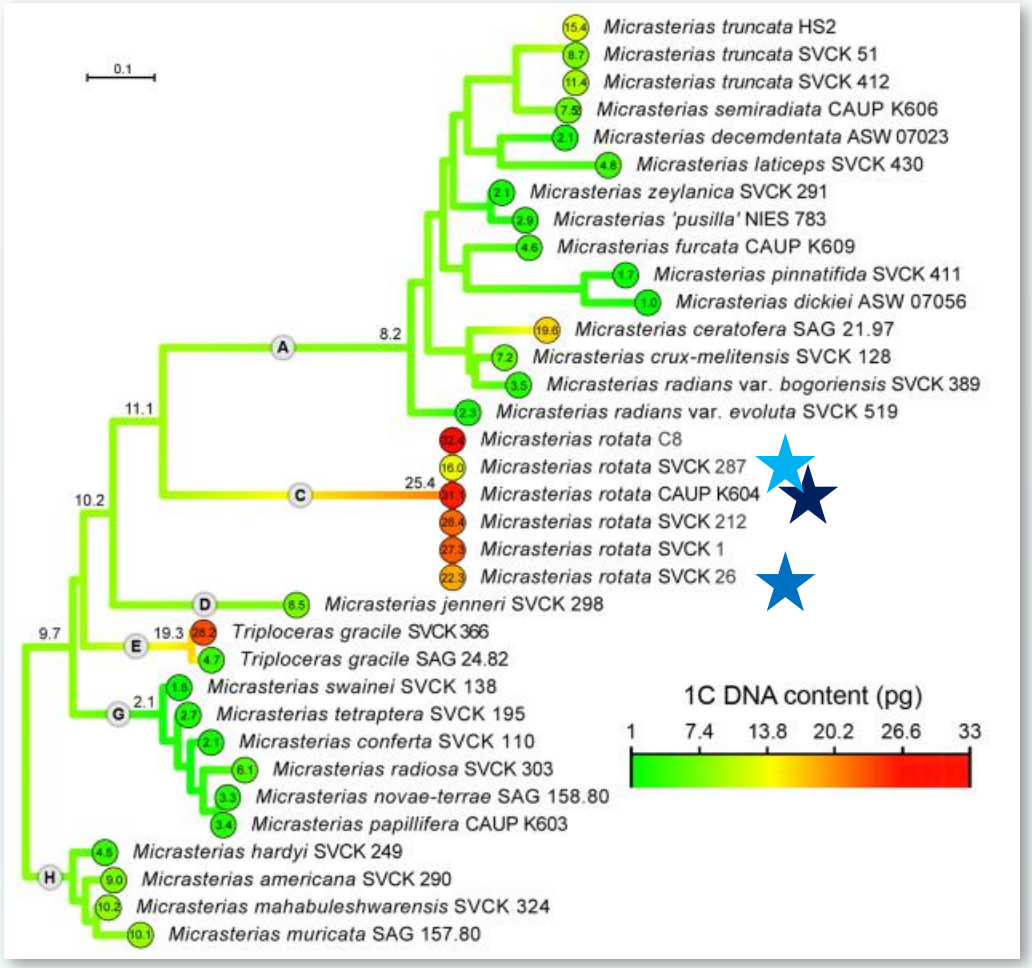


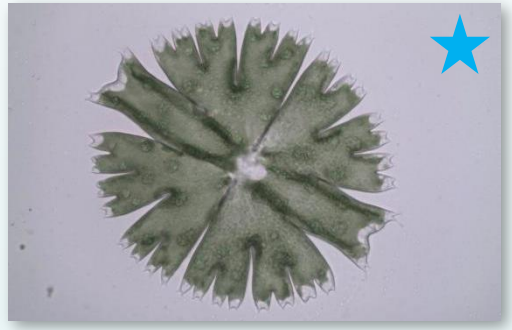
Rynearson al. (2006). *Microb. Ecol.* **53**: 549-561

Mechanisms of protist speciation

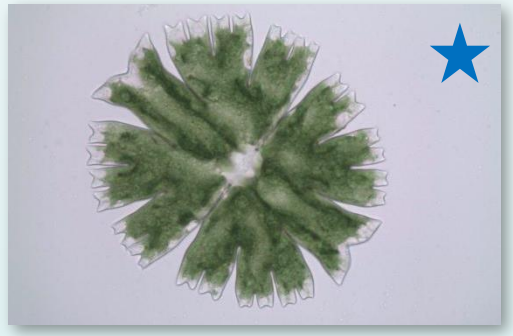
4. Polyploidisation

- *Micrasterias* = DNA content 2.1-39.2 pg ≈ 17-250 chromosomes

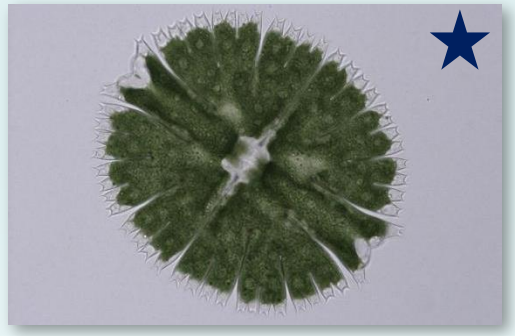




SVCK 287 ≈ 159 chromosomes



SVCK 26 ≈ 226 chromosomes



CAUP K604 ≈ 250 chromosomes

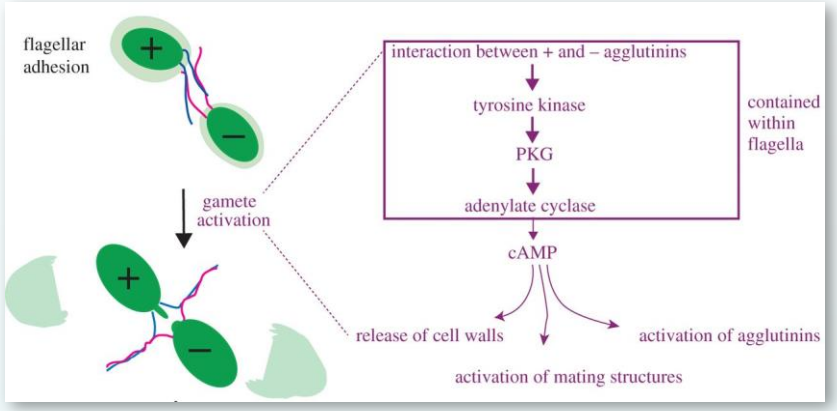
Poulíčková, Mazalová, Vašut, Šarhanová, Neustupa & Škaloud (2014). *Plos ONE* **9**: **e86247**

Mechanisms of protist speciation

5. Gametic incompatibility

- *Chlamydomonas, Pandorina*

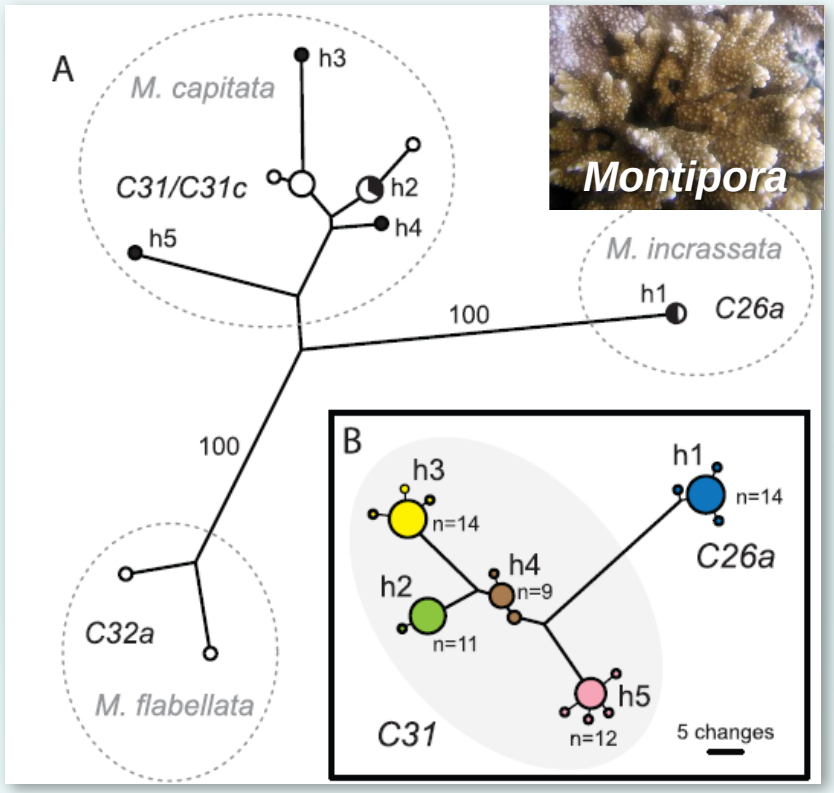
Coleman (2001). *J. Phycol.* **37**: 836-851



6. Host specificity

- *Symbiodinium*

LaJeunesse & Thornhill (2011). *Plos ONE* **6**: e29013



7. Monopolization

- *Chlamydomonas, Ochromonas, Oxytricha*

Weisse et al. (2011). *Ecosphere* **2**: 134

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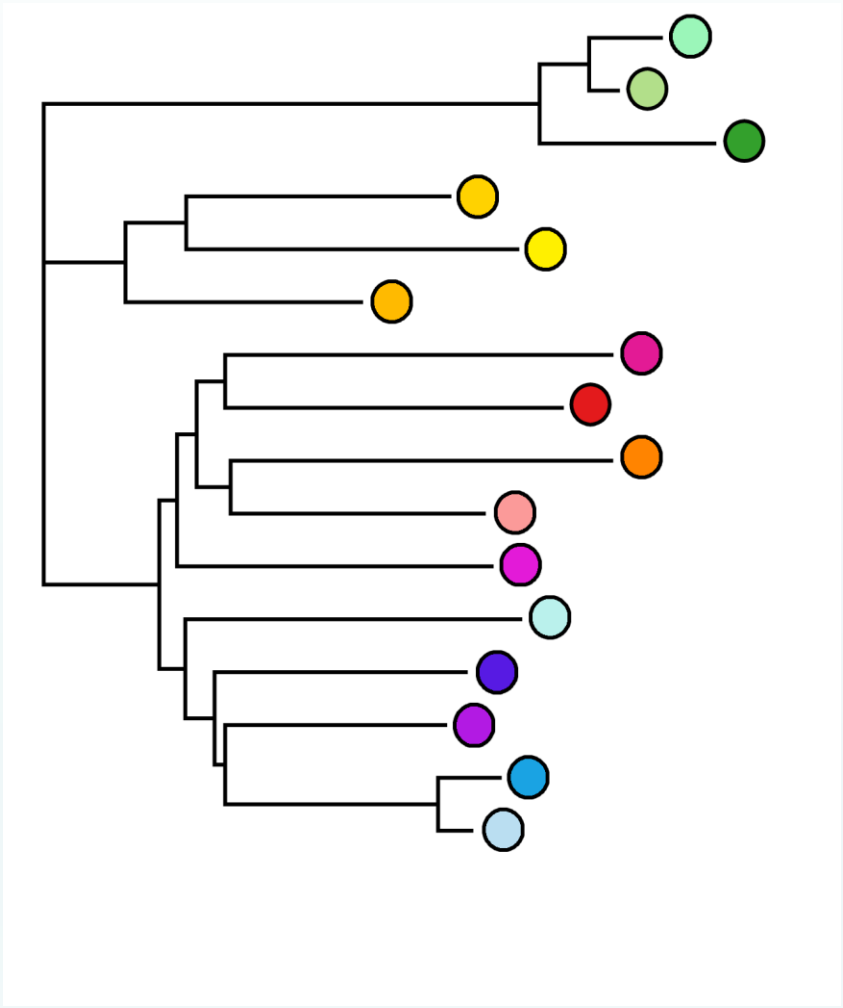
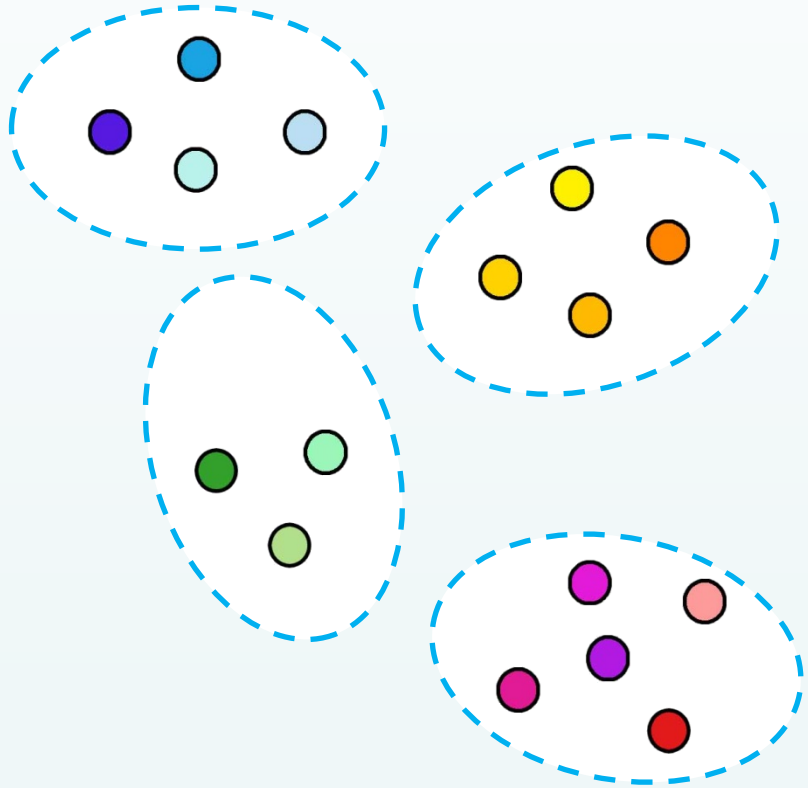
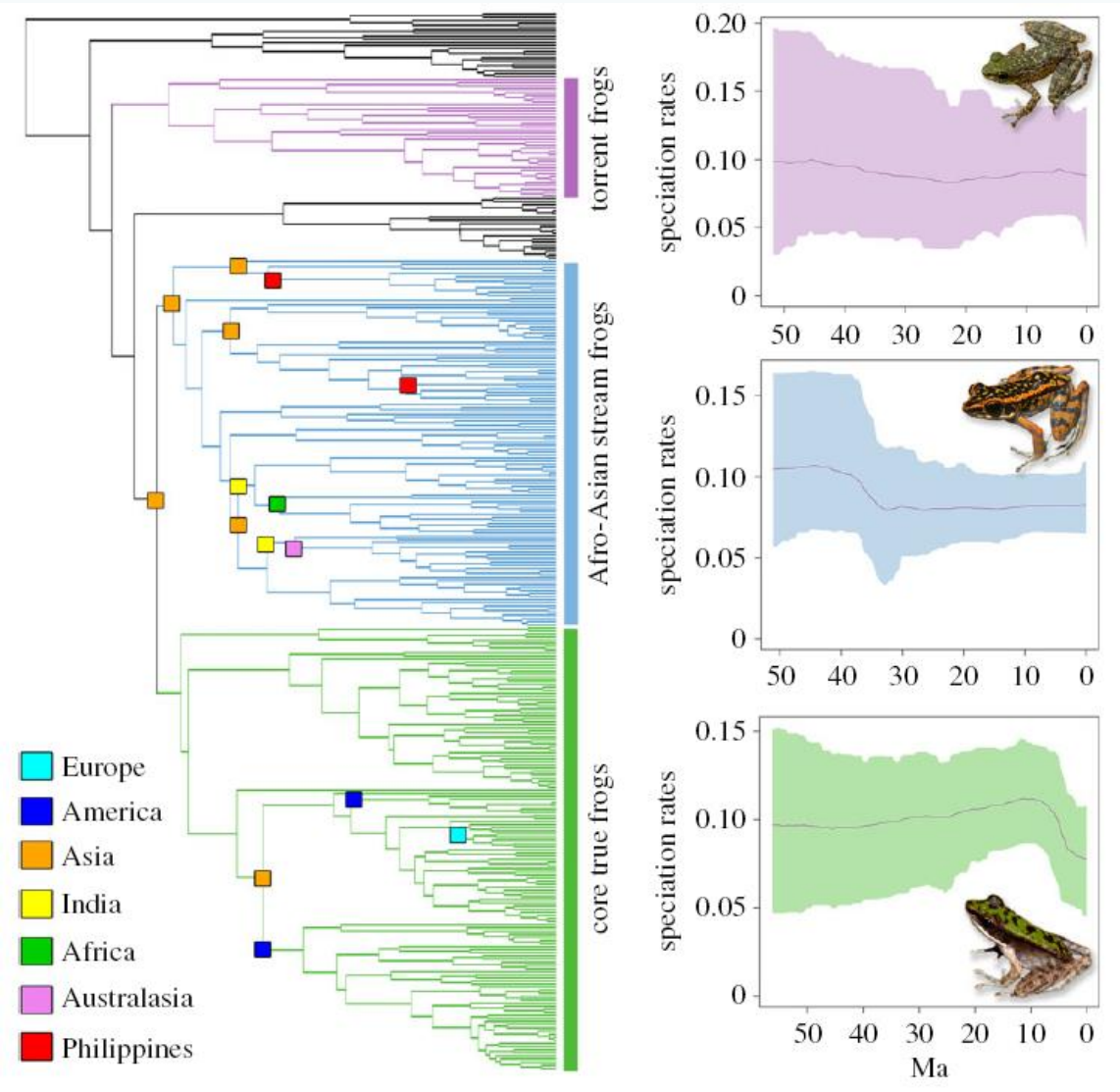
Testing speciation models





Testing speciation models

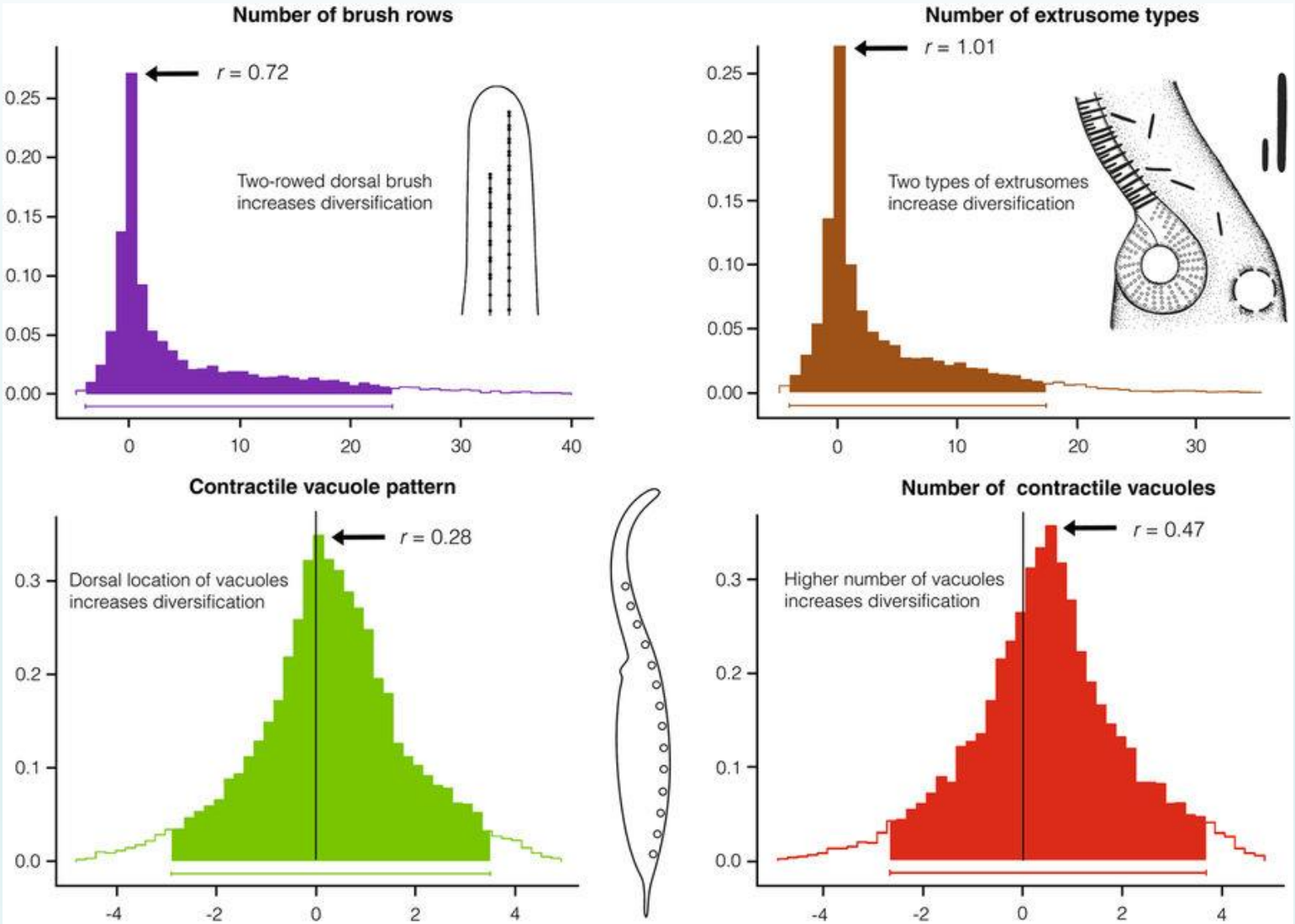
- Comparing speciation rates between the lineages



Chan & Brown (2017). *Biology Letters 1***3**: 20170299

Testing speciation models

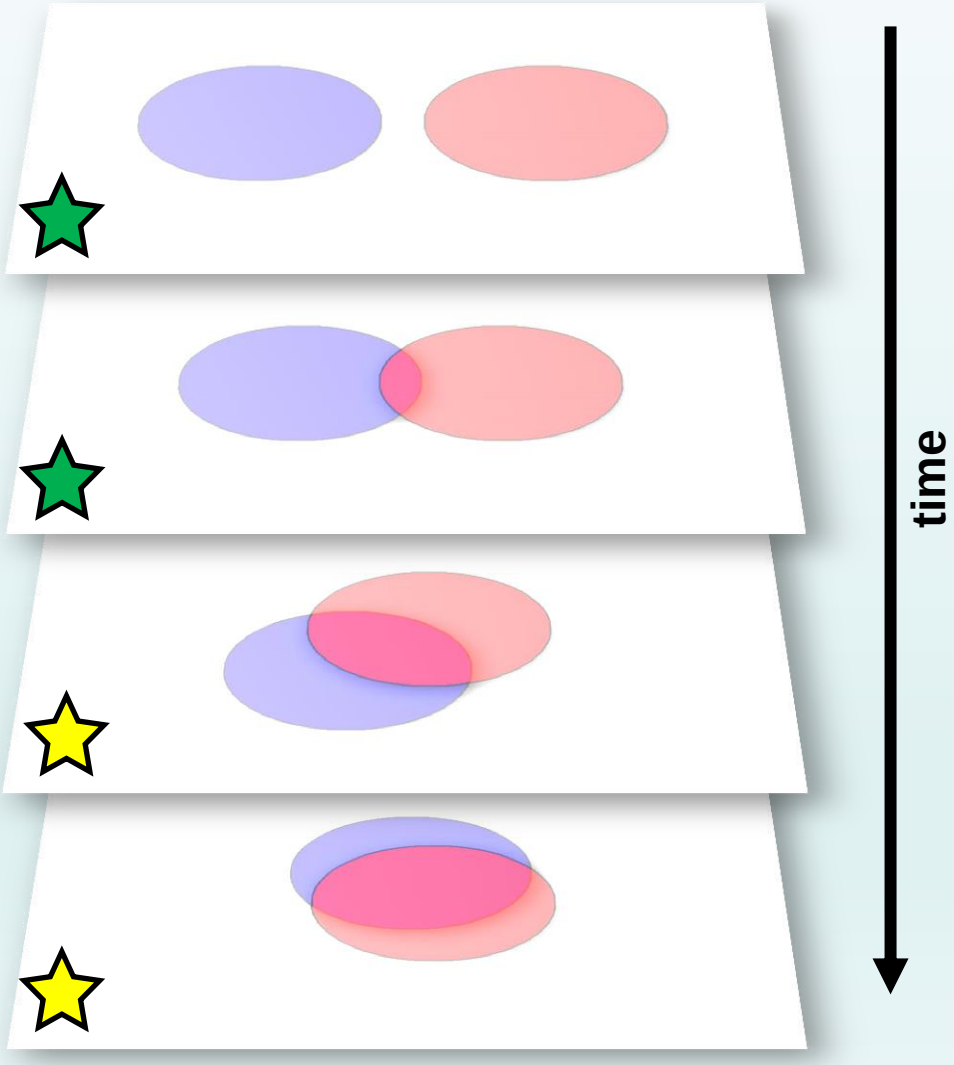
- Character-dependent speciation rates

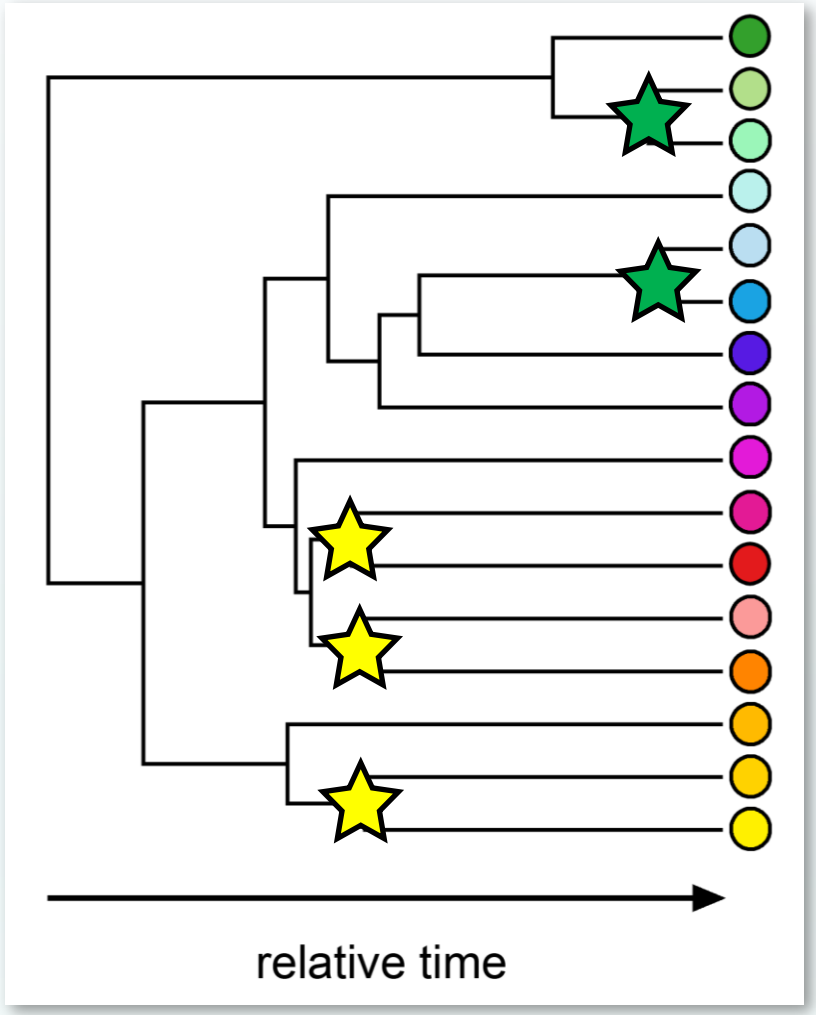


Vďačný et al. (2017). *Scientific Reports* **7**: 9918

Testing speciation models - overlaps

- **Speciation by geographic isolation** – over time, the amount of overlap between the geographic ranges of species can only increase from zero.





Testing speciation models - overlaps

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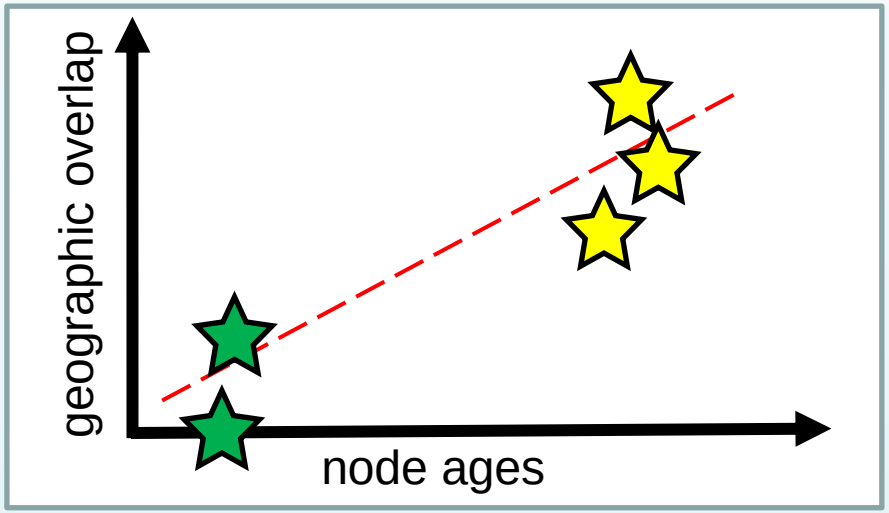
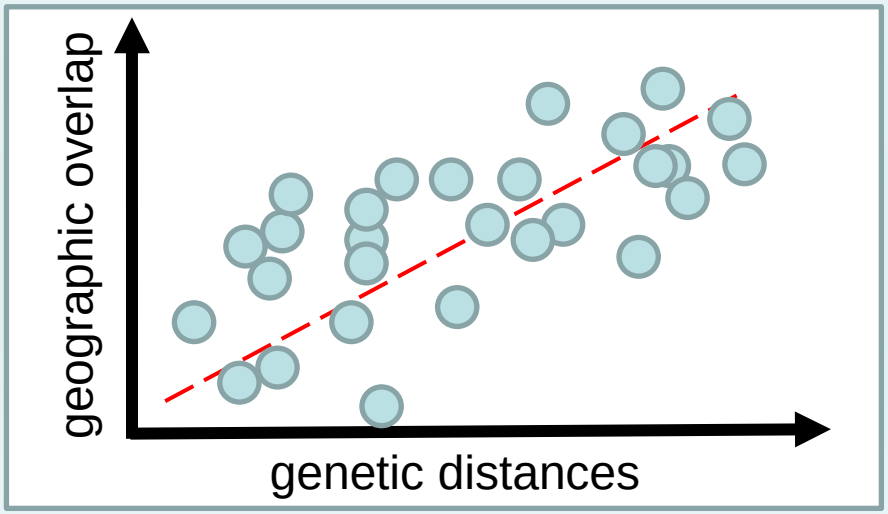
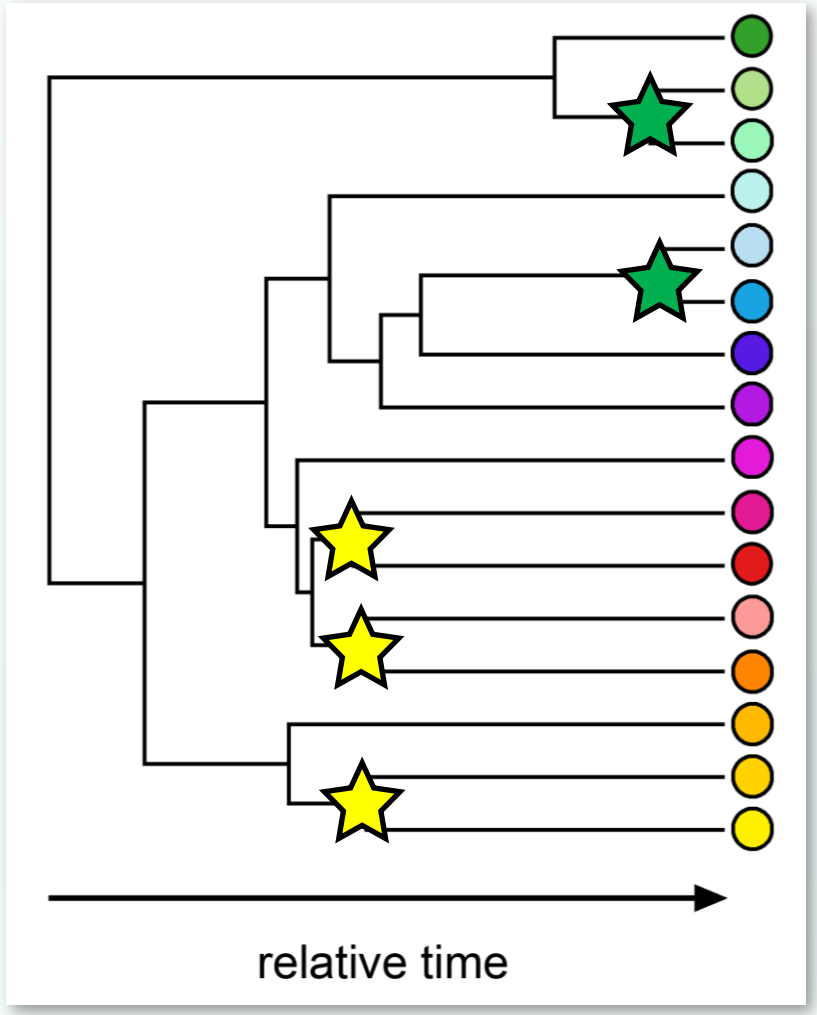
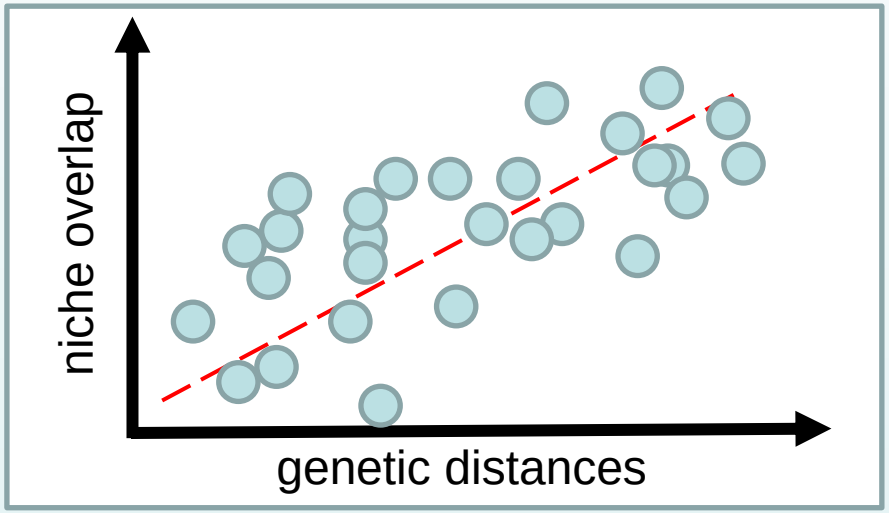


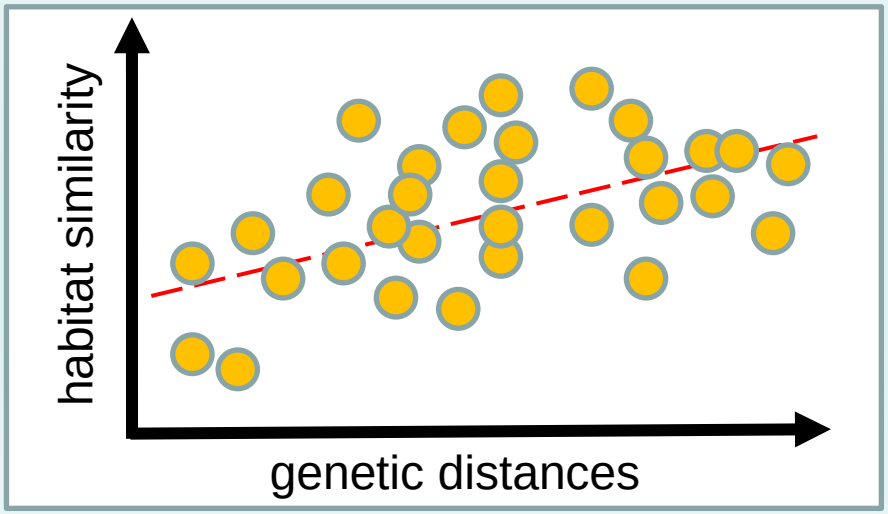


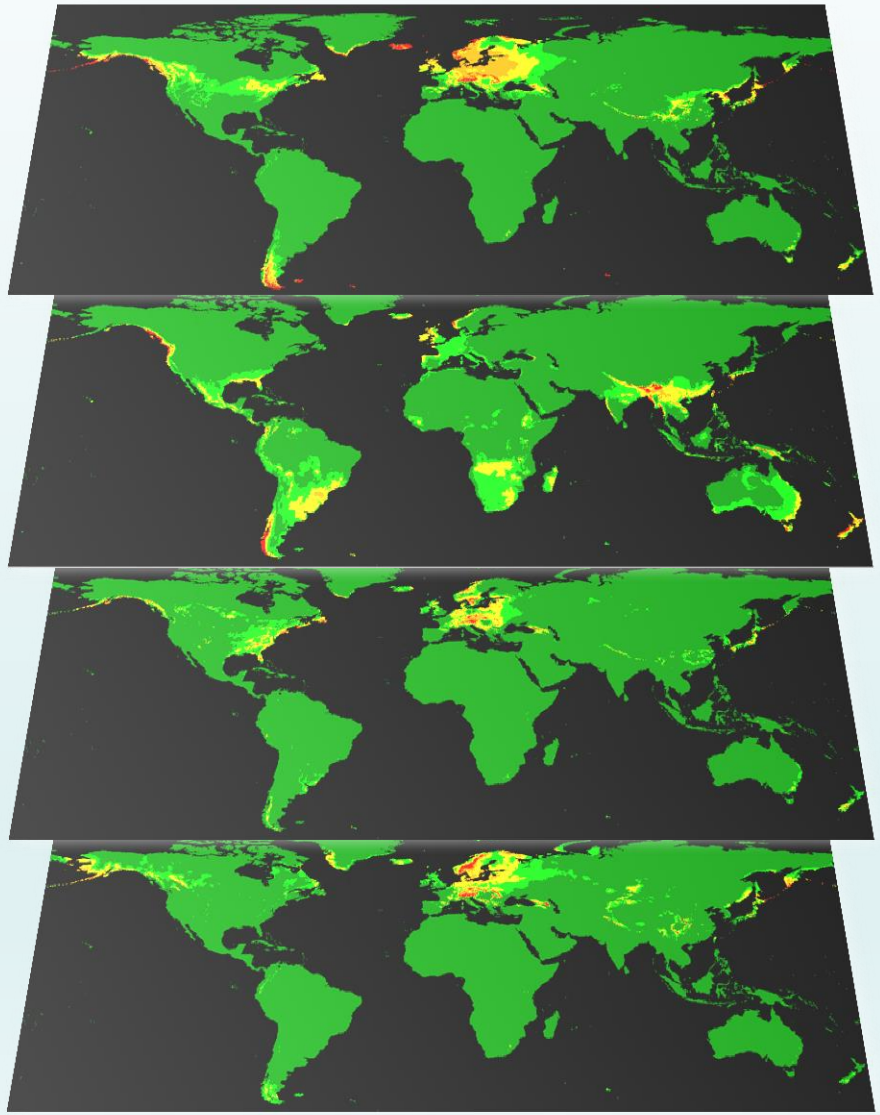


Testing speciation models - overlaps

- **Speciation by ecological isolation** - niche differentiation, habitat similarity

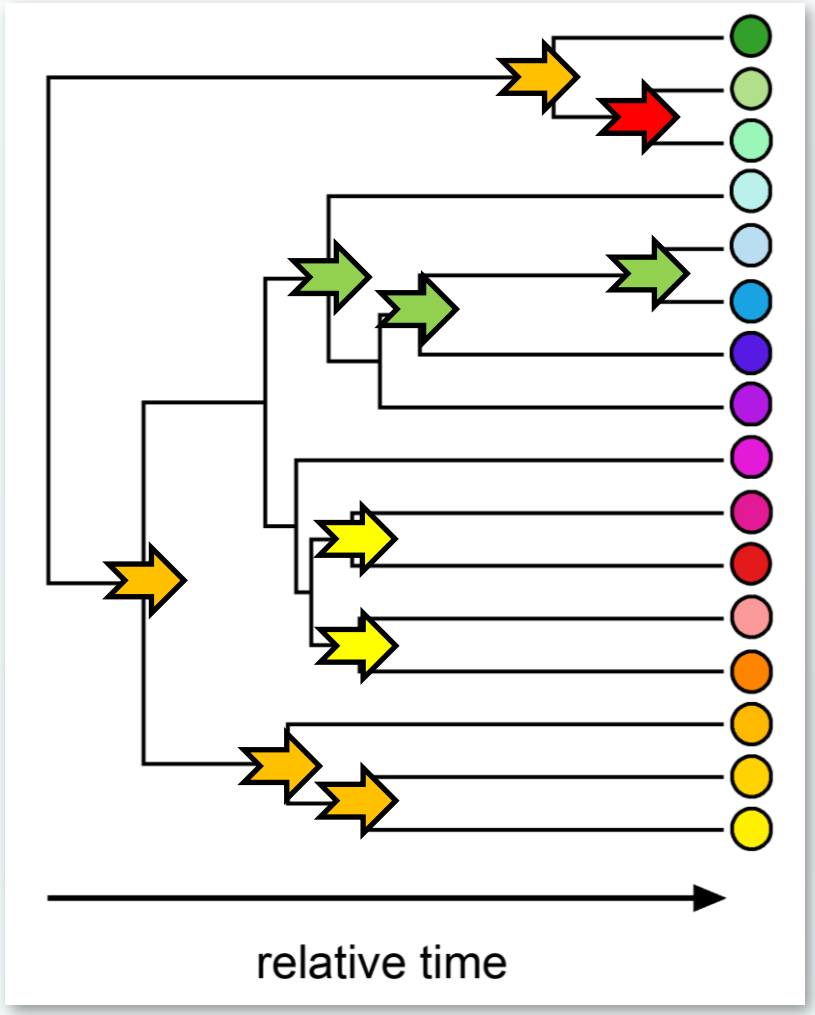


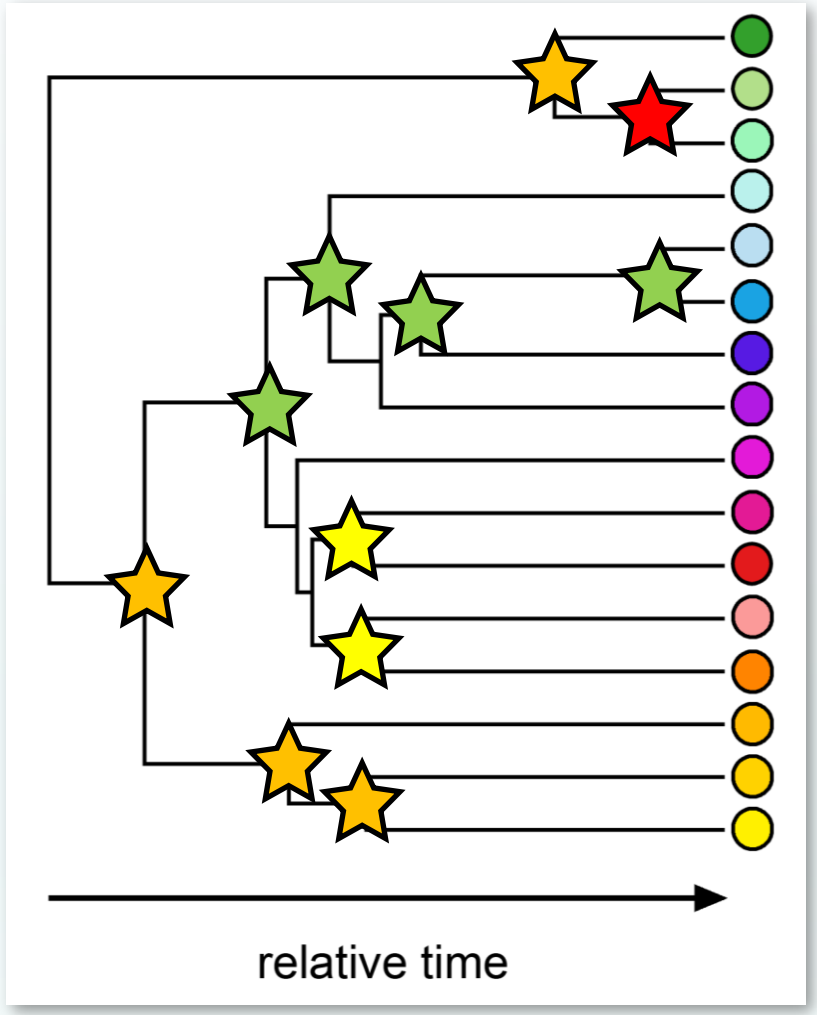




Testing speciation models – rate correlations

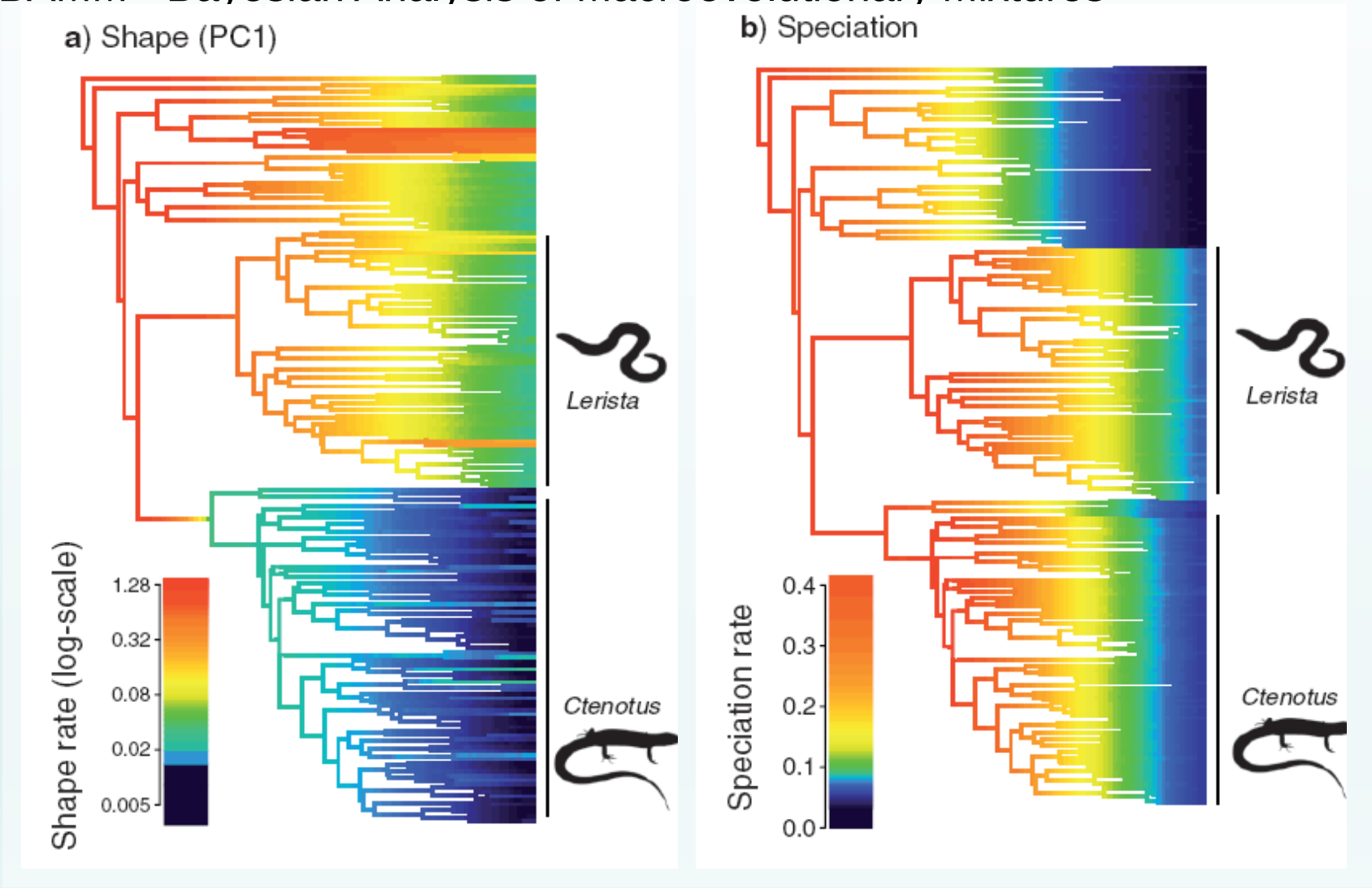
- **Rate comparisons** – in general, speciation rates should be correlated with the main drivers of speciation





Testing speciation models – rate correlations

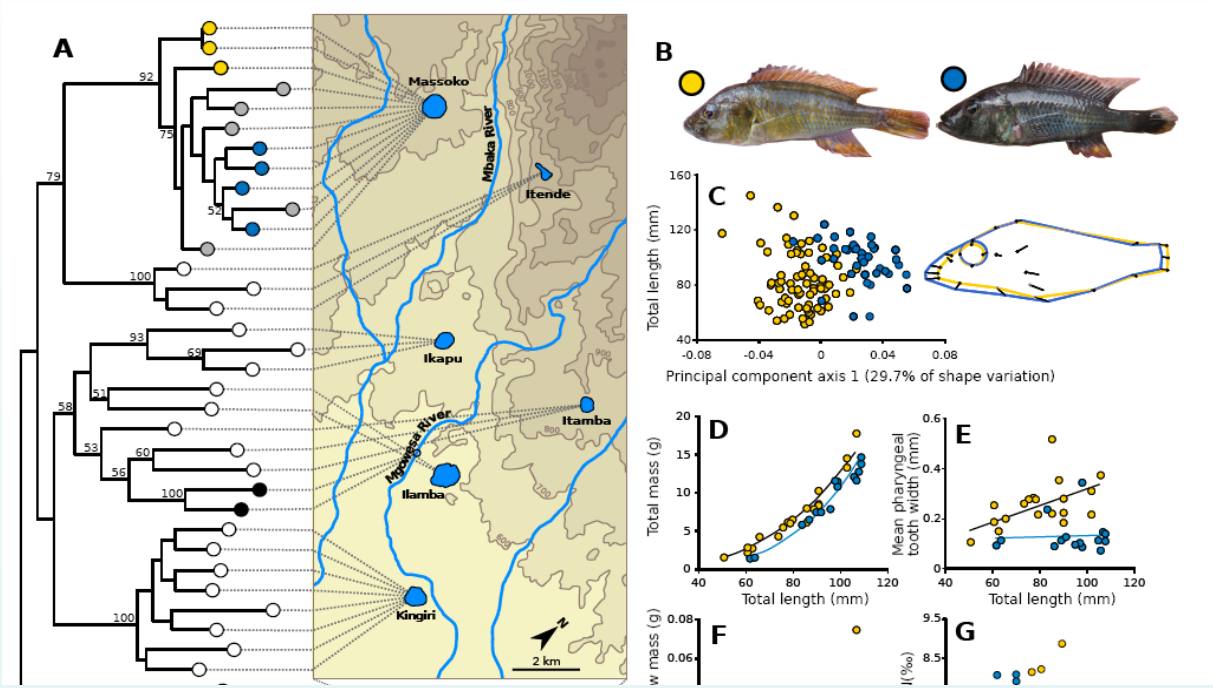
- Comparison of speciation rates with phenotypic change, BAMM
- BAMM - Bayesian Analysis of Macroevolutionary Mixtures



Rabosky et al. (2014). *Systematic Biology* **63**: 610-627

Testing speciation models

- Genomic islands



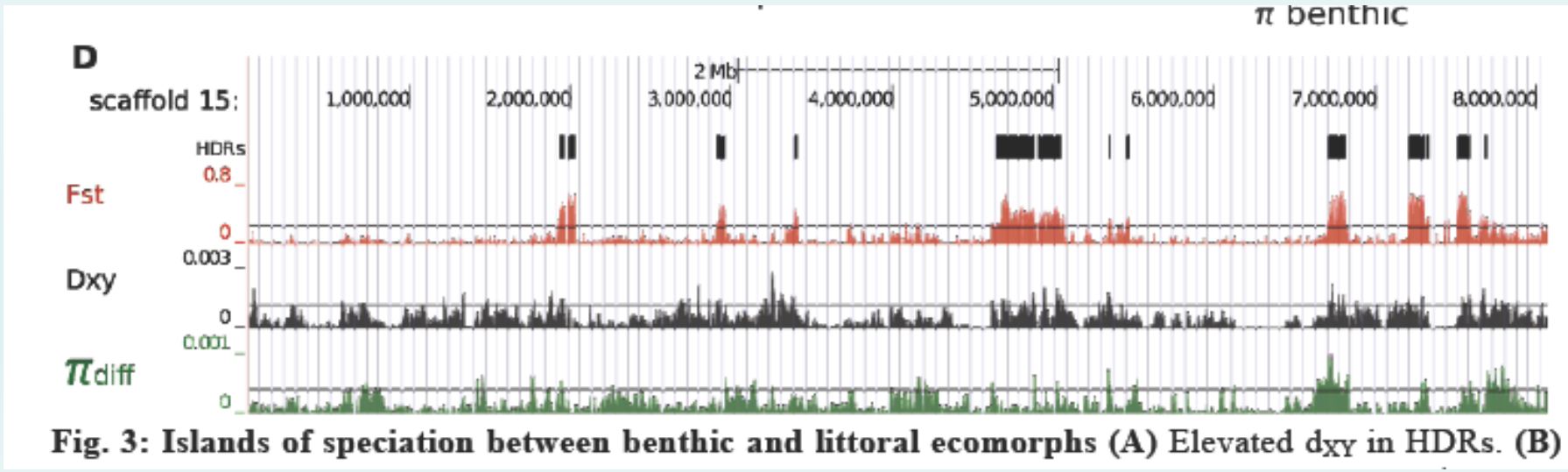
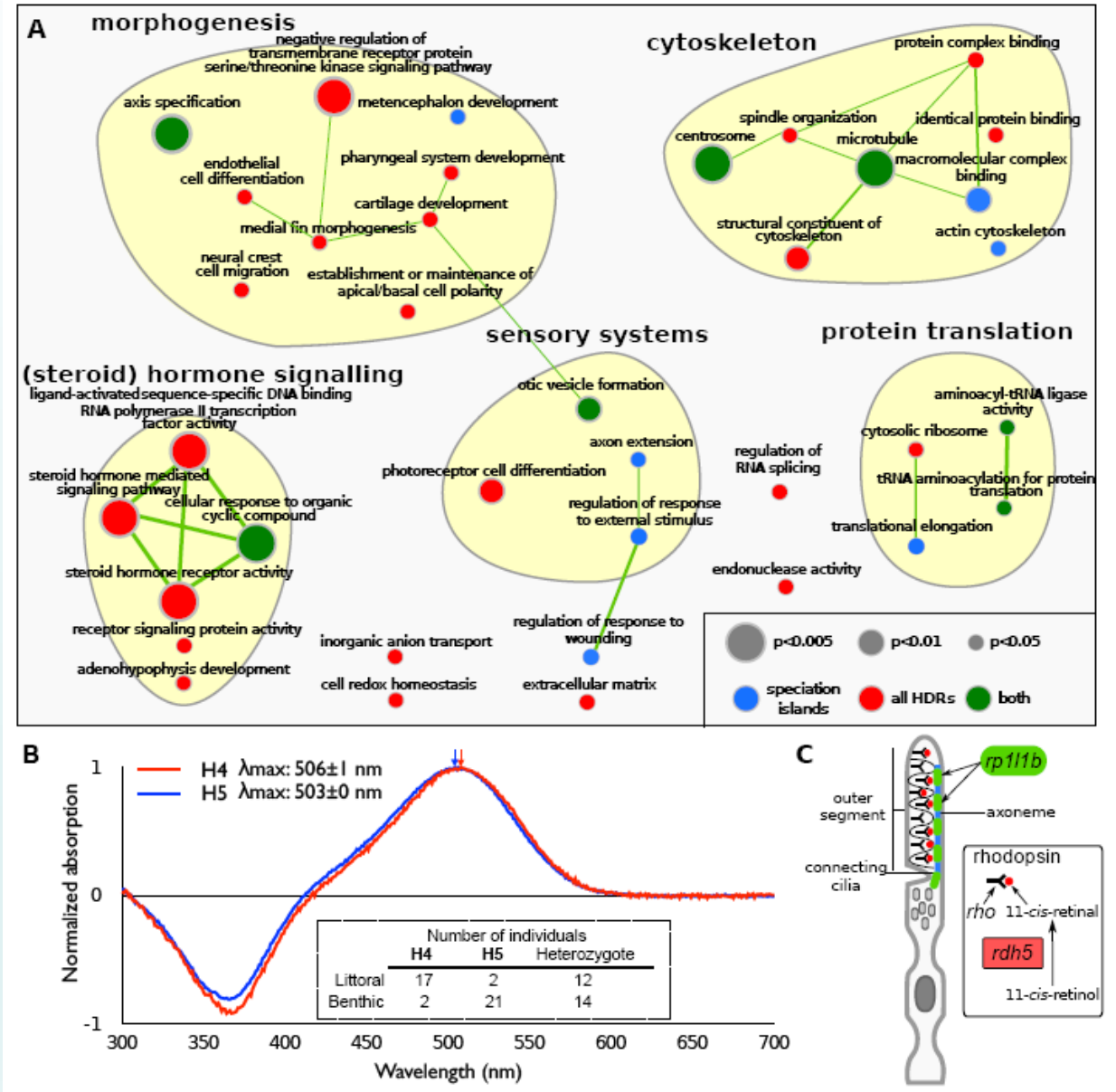


Fig. 3: Islands of speciation between benthic and littoral ecomorphs (A) Elevated d_{XY} in HDRs. (B)

Malinsky et al. (2015). *Science* **350**: 1493

Testing speciation models

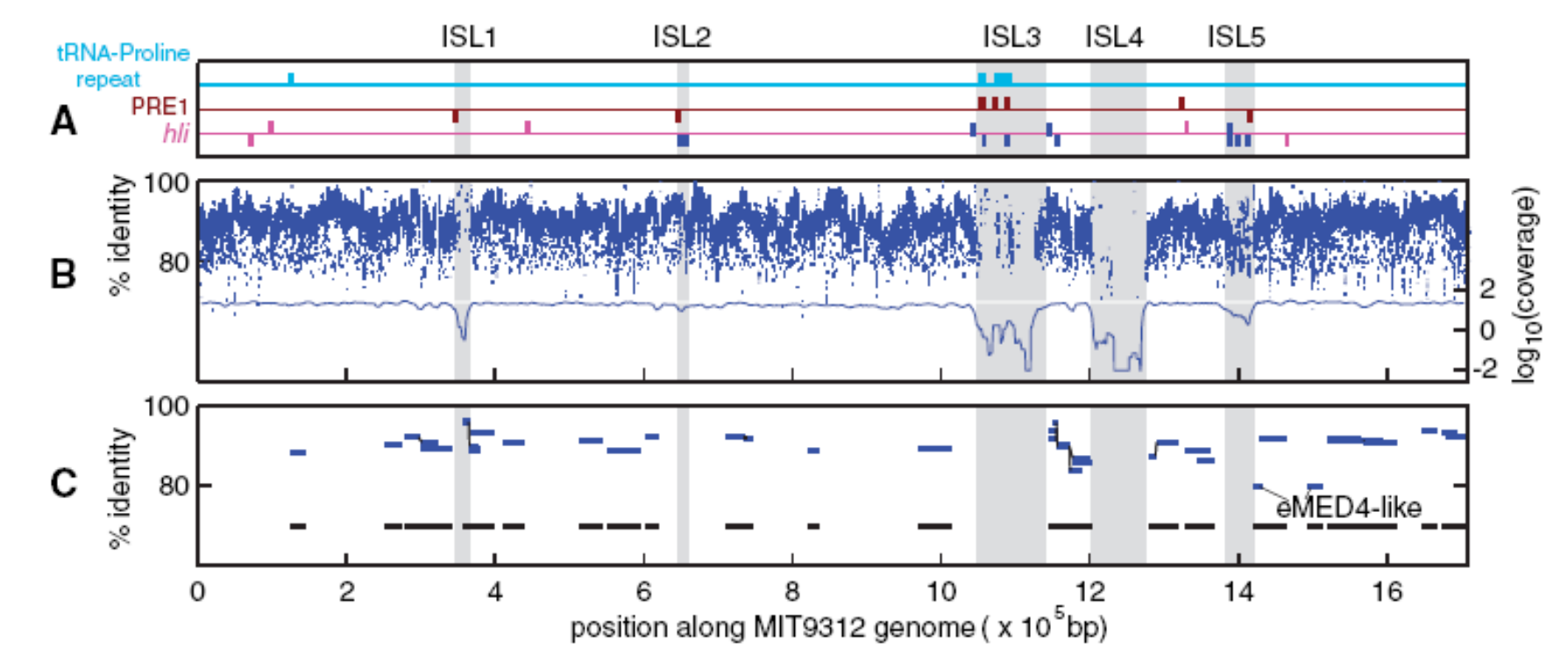
- Genomic islands



Malinsky et al. (2015). *Science* **350**: 1493

Testing speciation models

- Genomic islands – *Prochlorococcus*



Coleman et al. (2016). *Science* **311**: 1768


Thank you for your attention