Speciation & hybridization

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Outline

What are species ?

Speciation

Hybridization

Geographic modes of speciation

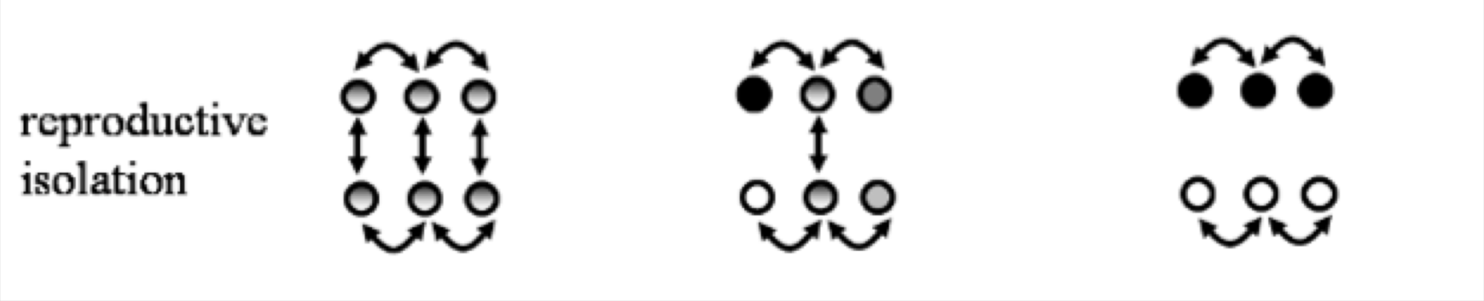
Barriers to gene flow

Genomics of speciation

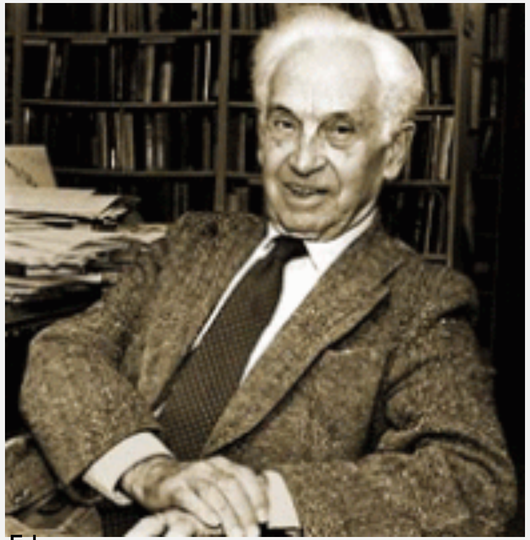
Phylogenetics

What are species ?

- **Biological species concept (BSC):** Species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups (Mayr, 1942).

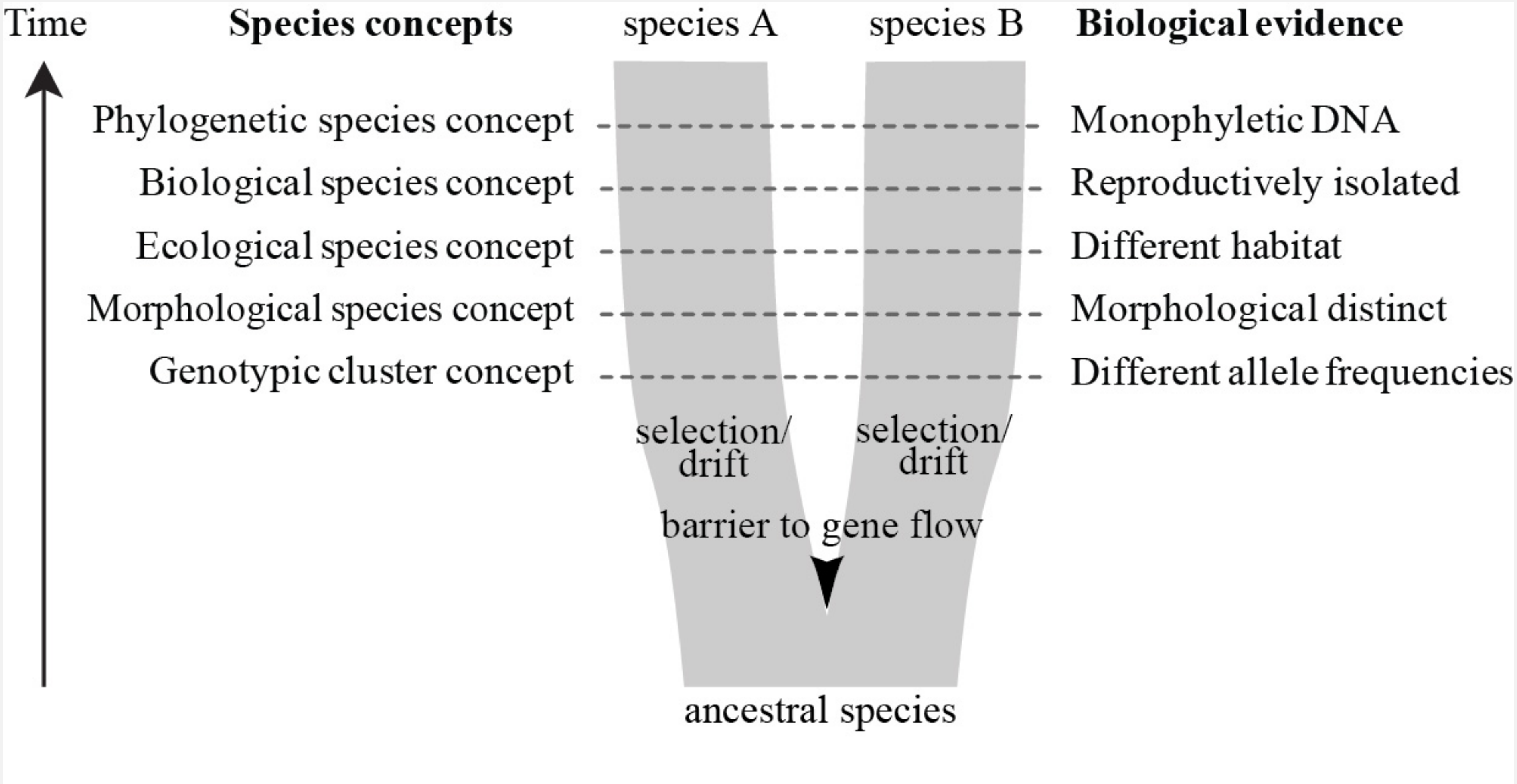


Nosil et al. (2009), *Trends in Ecology & Evolution*



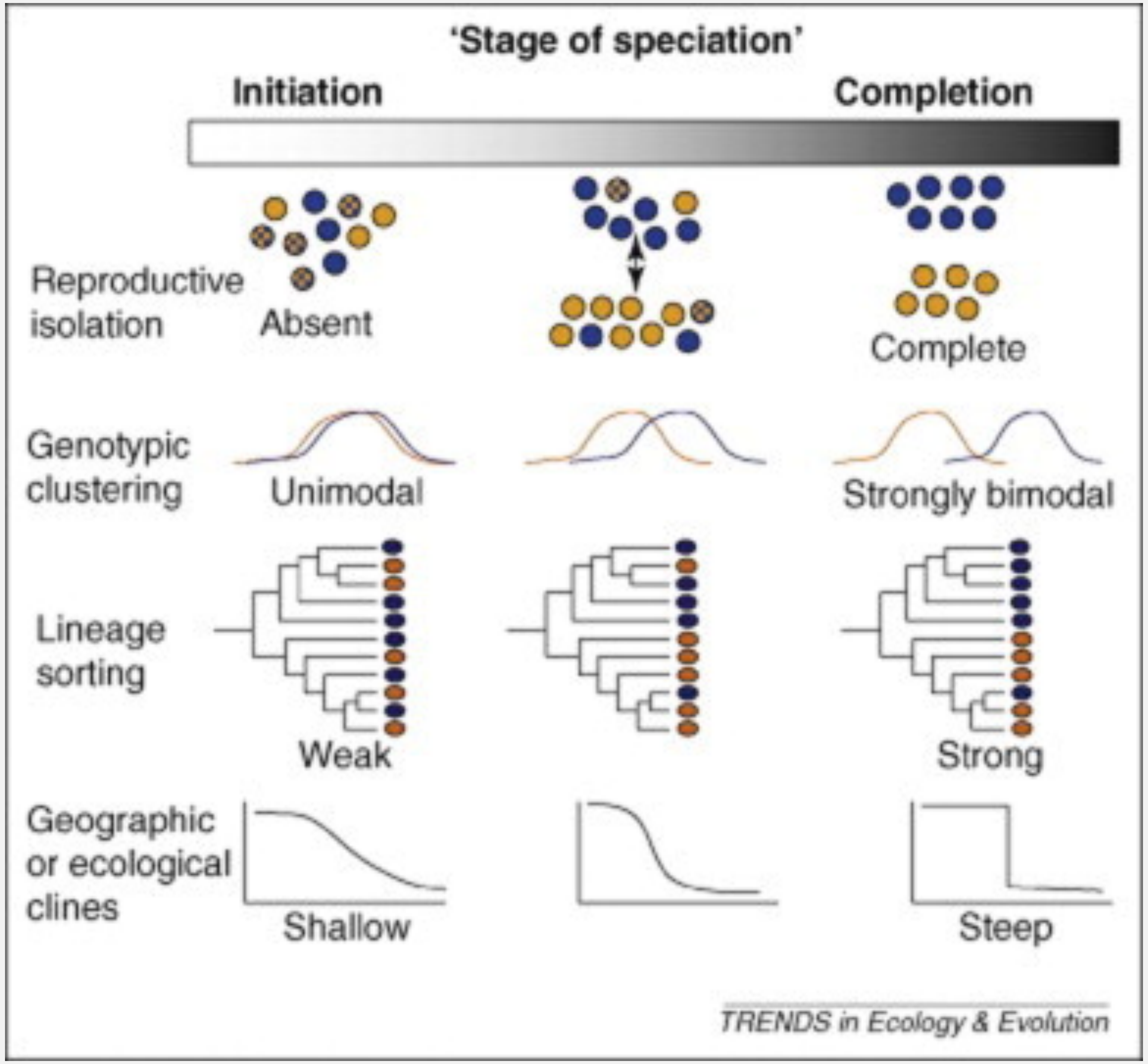
Edge.org

Other species concepts



Leliaertet al. (2014), *European Journal of Phycology*

Speciation continuum



Nosil al. (2009)

Biological species concept (BSC):

PROS

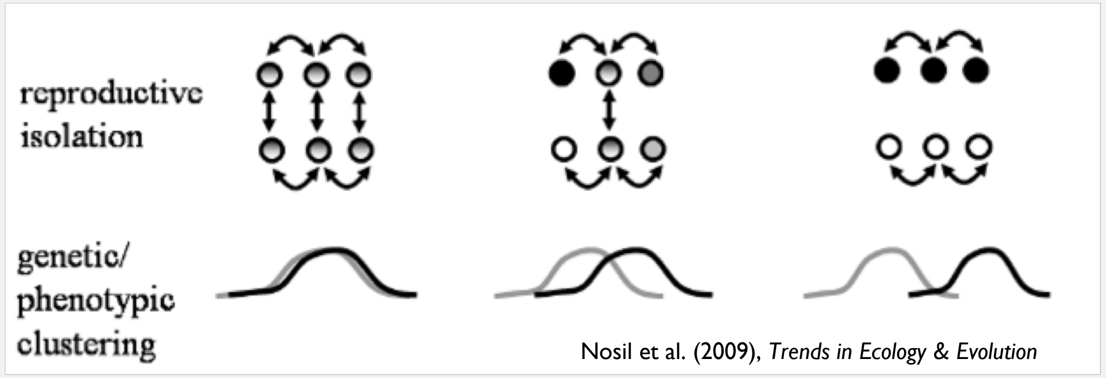
- Interbreeding explains why the members of a species resemble one another
- Reproductive isolation is caused by barriers to gene flow
- Gene pool = independent unit of evolution
- Organisms do not evolve but species do
- Species as a "harmonious" gene pool

CONS

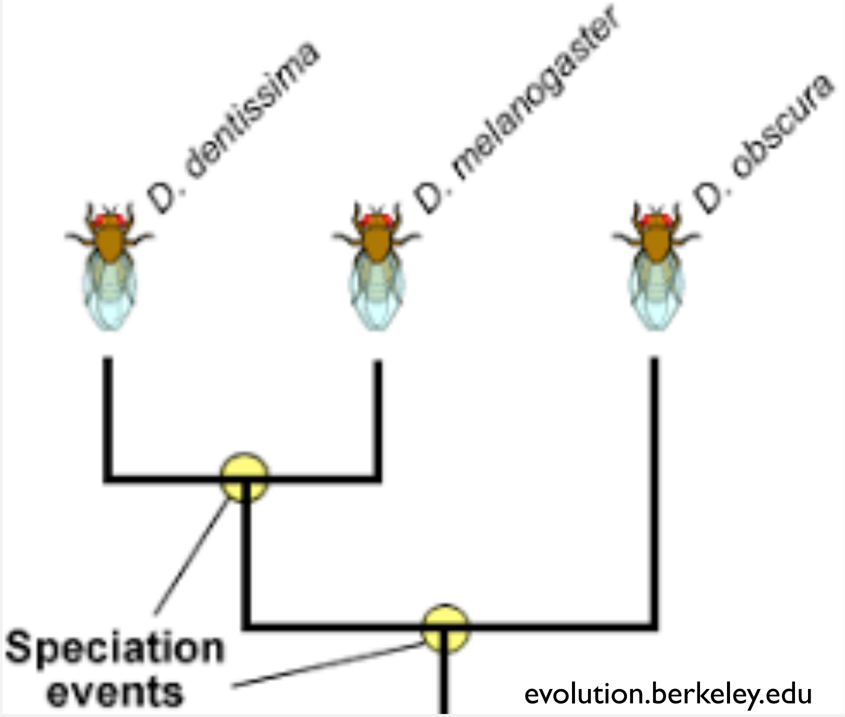
- Asexual reproduction
- Fossil species
- Hybrids

Speciation

- The origin of two or more species from a common ancestral one
- Barriers to gene flow
- Reproductive isolation (RI)
- Discrete and interbreeding genetic pools



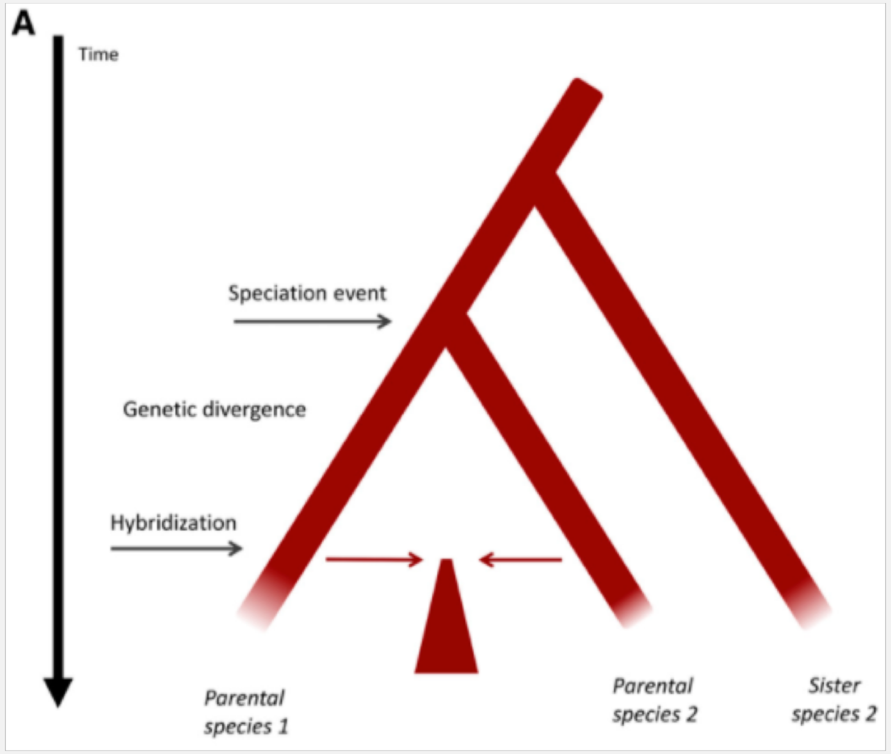
Nosil et al. (2009), *Trends in Ecology & Evolution*

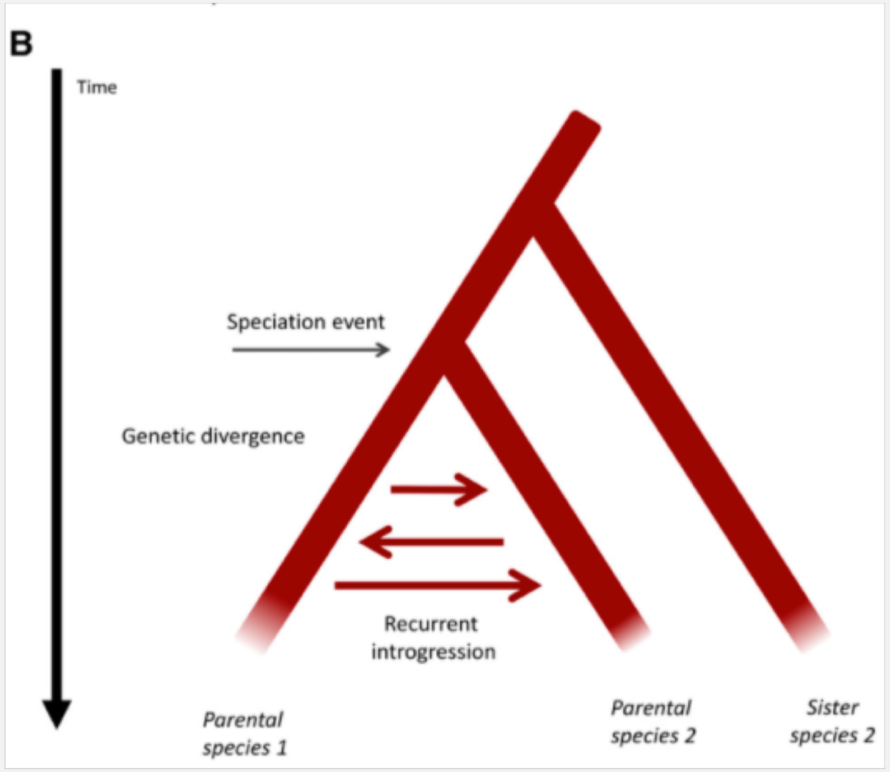


evolution.berkeley.edu

Hybridization

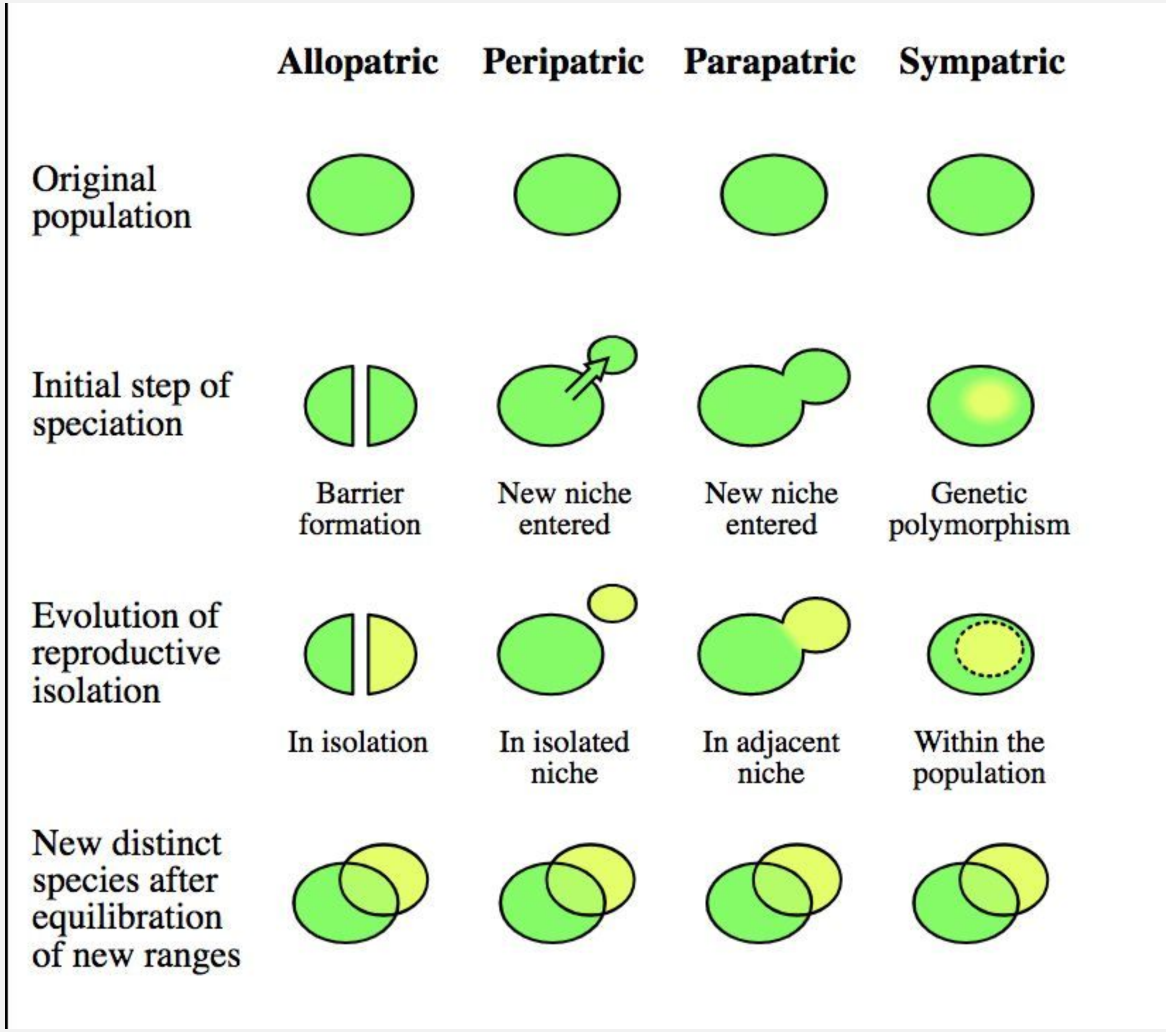
- Interbreeding between species or divergent populations
- Introgression: incomplete postmating isolation





Stukenbrock (2016), *Phytopathology*

Geographical modes speciation



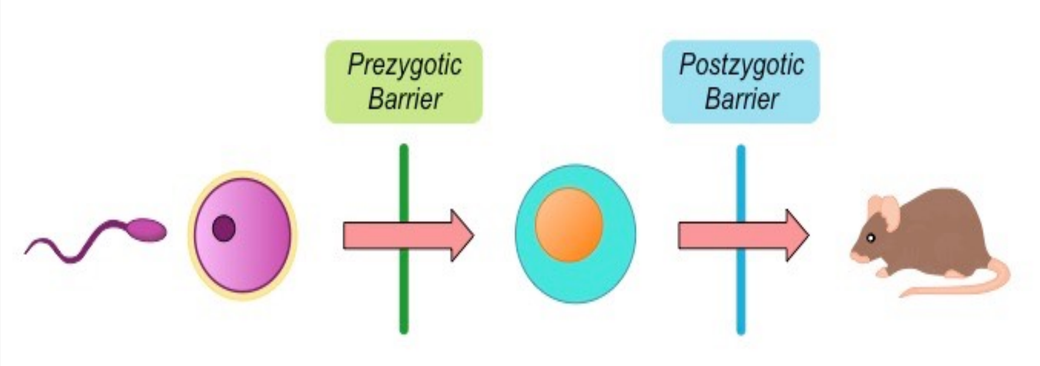
www.nationalgeographic.org/encyclopedia/speciation

Barriers to gene flow

1. Premating/prezygotic: Features that impede transfer of gametes to members of other species

2. Postmating and prezygotic: Mating or gamete transfer occurs, but zygotes are not formed

3. Postzygotic: zygotes are formed but have reduced fitness



http://ib.bioninja.com.au

1.Premating/prezygotic

A) Ecological isolation:

➢Potential mates in the same area do not meet

- Habitat: spatially segregated

Ladybird beetles in Japan exclusively mate on its own host plant

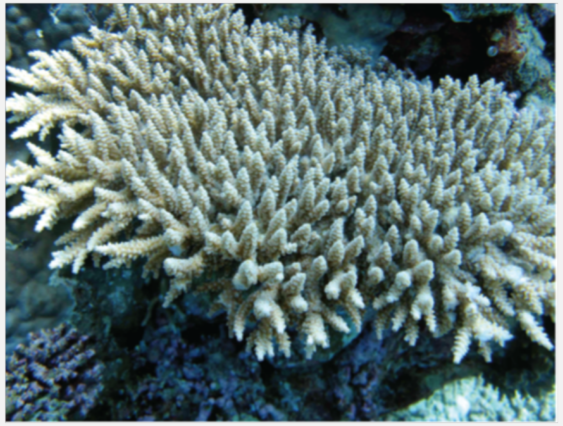
Epilachna niponica and *E. yasutomii*

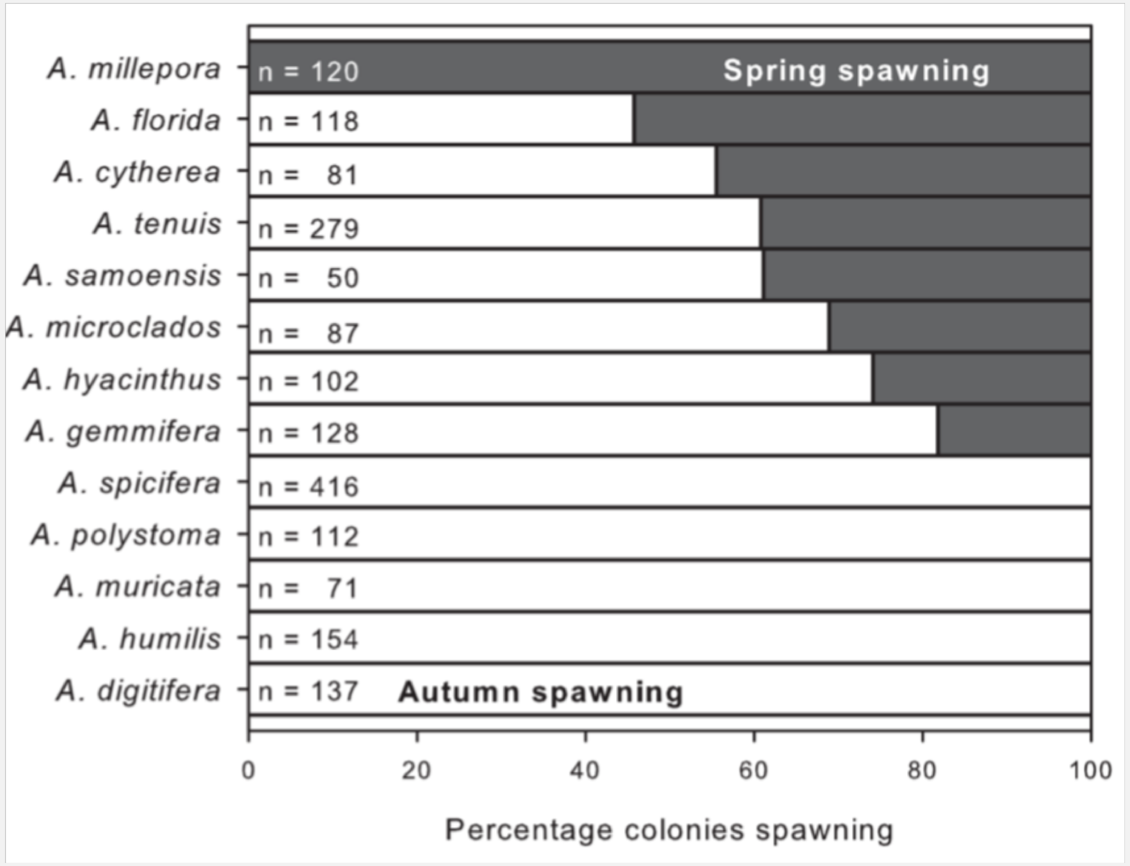
Kakatura (1997), *Zoological Science*

1.Premating/prezygotic

Ecological isolation:

- Temporal: populations breed at different seasons or times of day
- *Acropora spp.* Indopacific



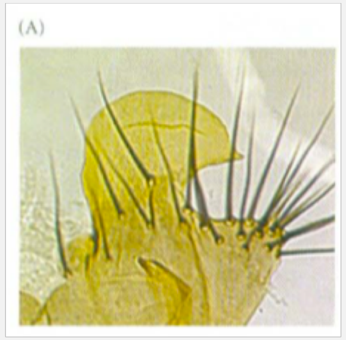


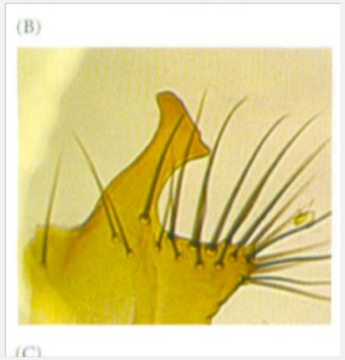
Gilmoure et al.(2016), *PLOS ONE*

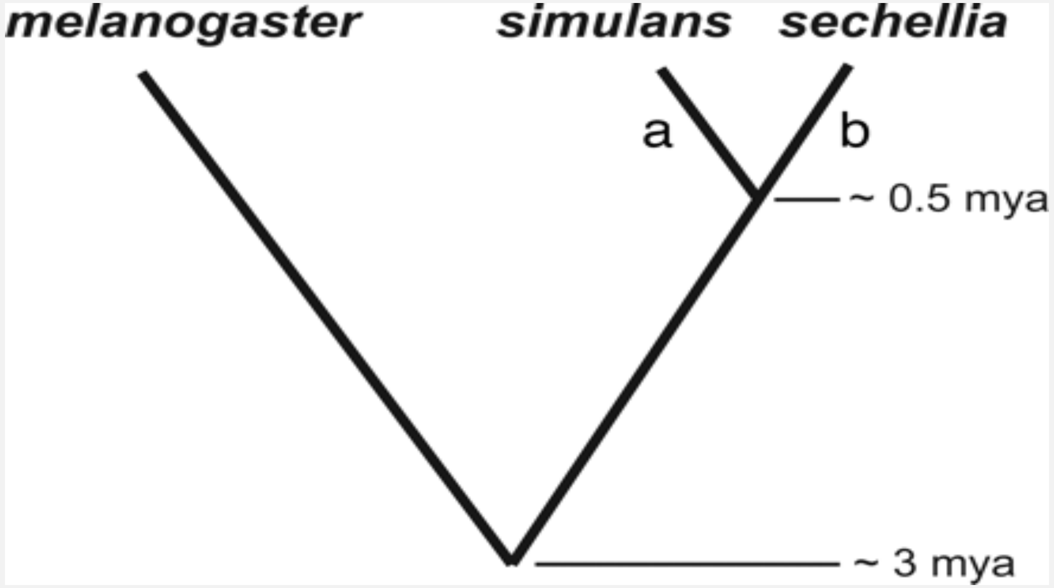
1.Premating/prezygotic

B) Copulatory isolation:
behavior/structure prevents copulation

"key-lock" genitalia in *Drosophila simulans* and *D. sechellia.*





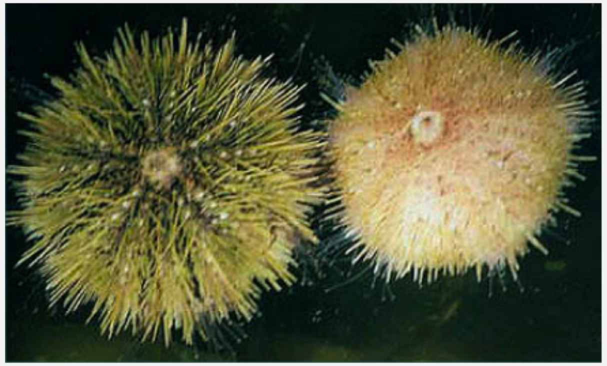


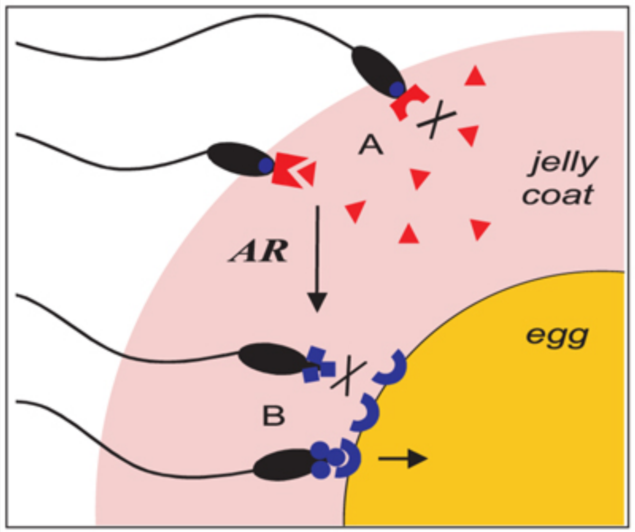
McBride (2007), *PNAS*

1.Premating/prezygotic

C) Gametic isolation:
Released/transferred gametes cannot effect fertilization

- *Strongylocentrotus droebachiensis* and *S. pallidus:* sperm-egg recognition proteins (bindin and bindin receptor)





Mourão (2007), *Braz J Med Biol Res*

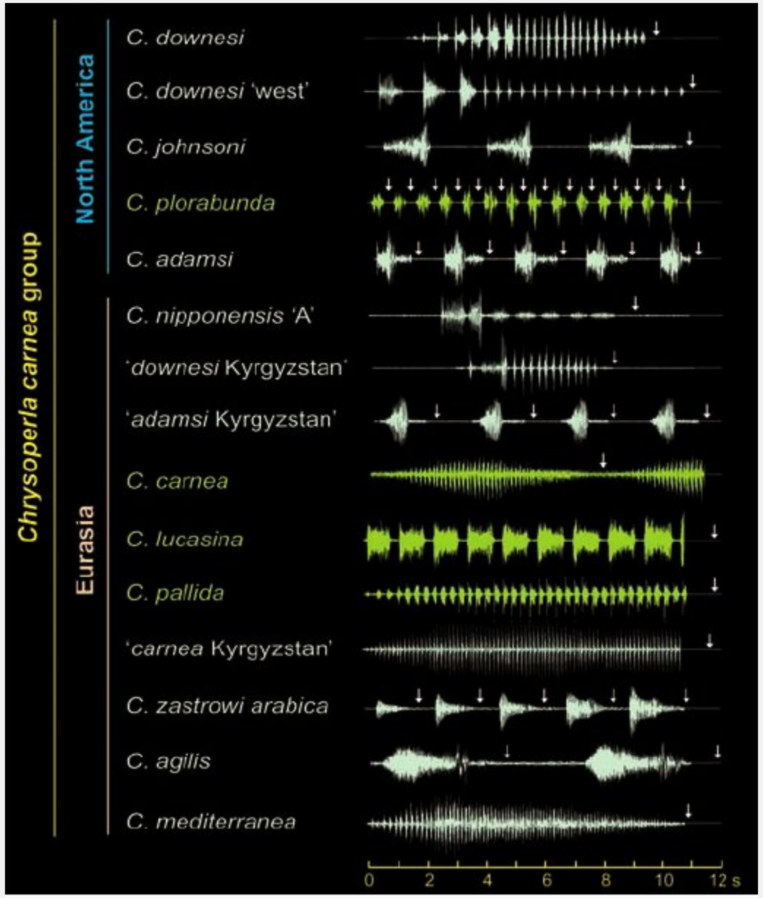
1.Premating/prezygotic

- Potential mates meet but do not mate

D) Behavioral isolation: the lack of cross attraction between members of different species.

Lacewing

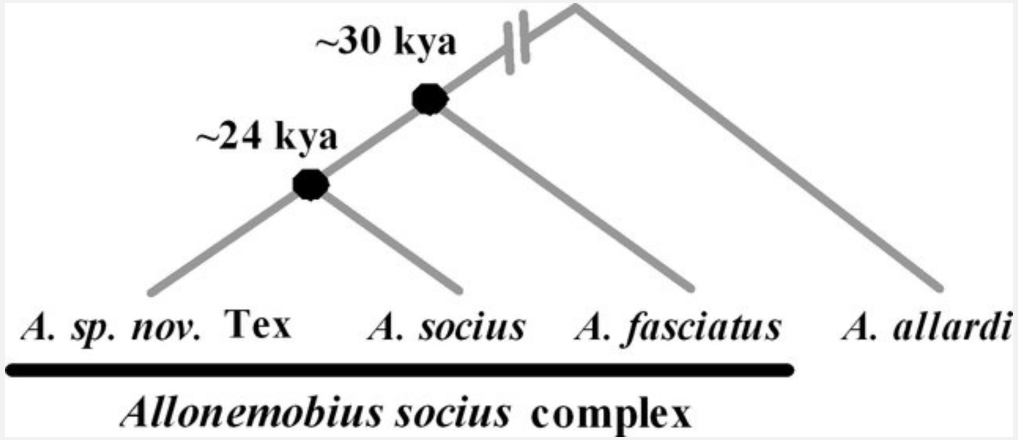
(*Chrysoperla spp.*)



Henry & Wells (1997), *American Entomologist*

2. Postmating and prezygotic

Conspecific sperm precedence: females are exposed to sperm from males of multiple species, but preferentially use sperm of a conspecific.

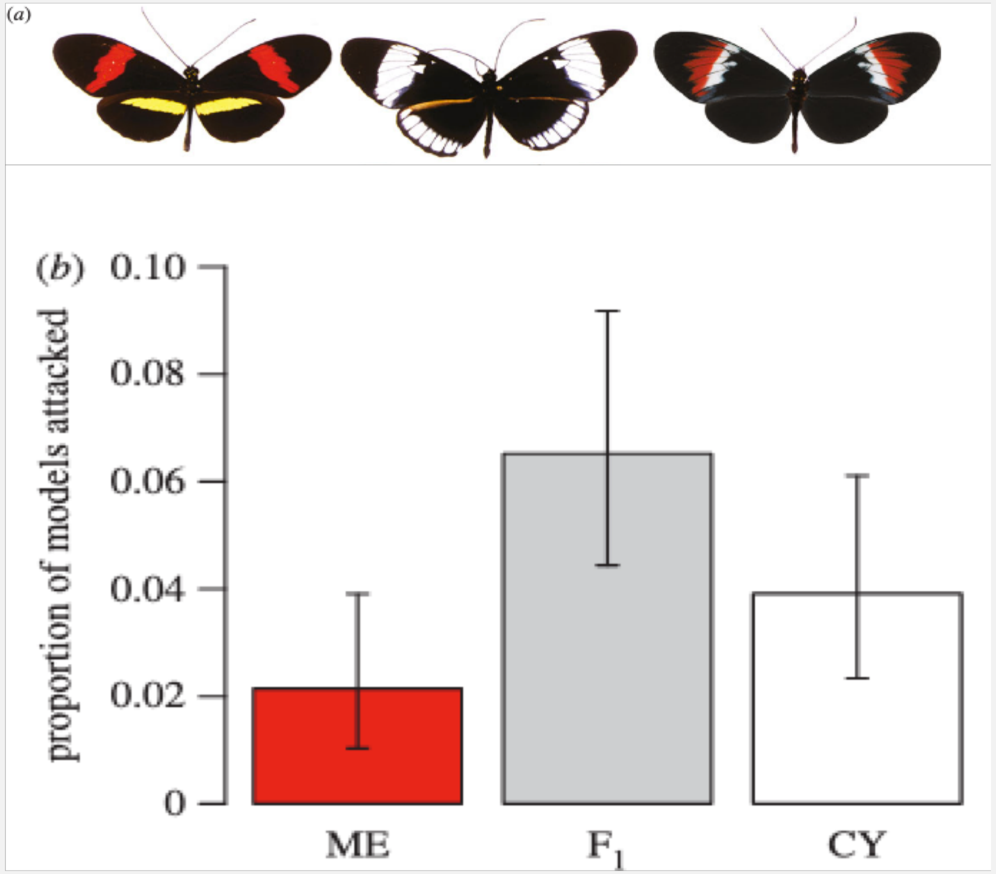


Marshall (2007), *PLOS ONE*

3. Postzygotic

A) Extrinsic: environment-dependent or lack of appropriate niche

Heliconius melpomene x *H. cydno* = hybrid



Merril et al. (2012) *Proc. R. Soc*

3. Postzygotic

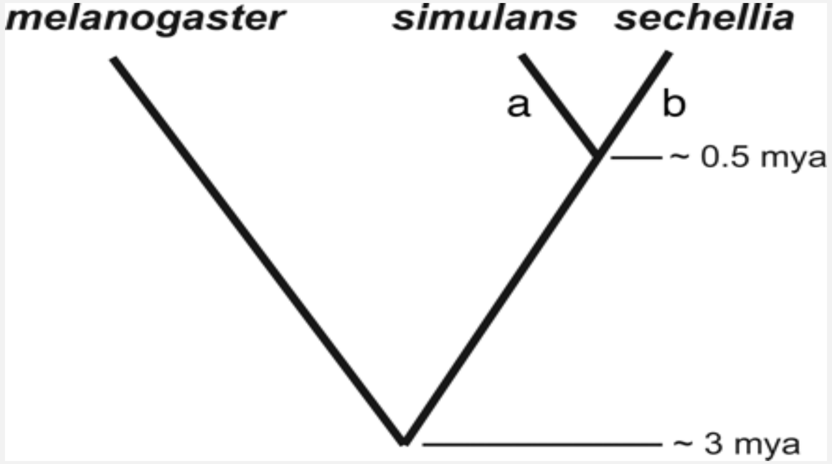
B) Intrinsic: genomic conflict

- Hybrid inviability

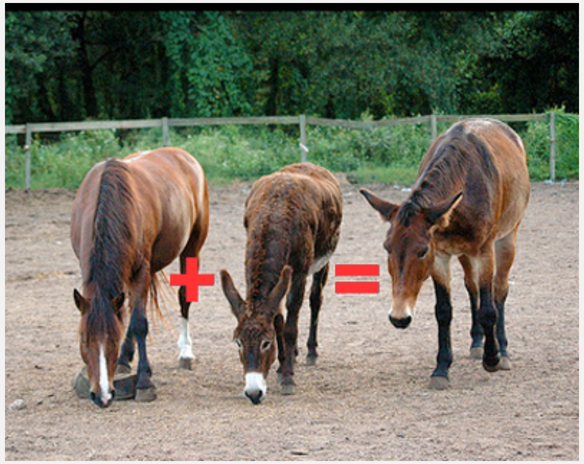
D. melanogaster x *D. simulans* = inviable zygotes

- Hybrid sterility

Mule



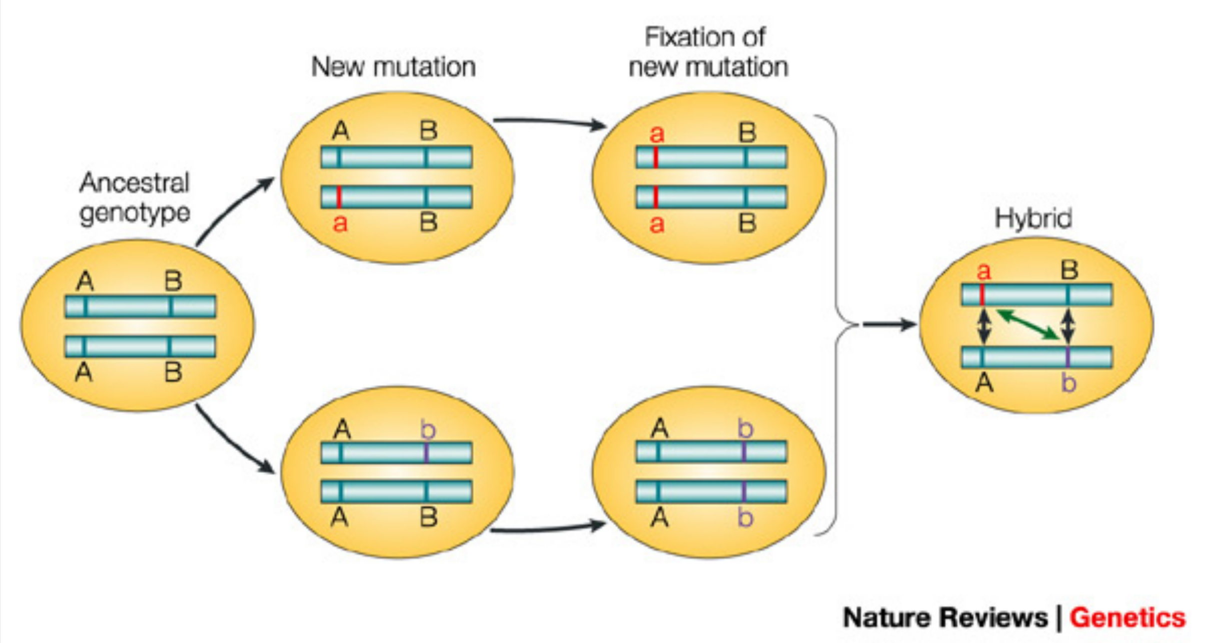
McBride (2007), *PNAS*



http://www.bio.miami.edu

3. Postzygotic

- **Dobzhansky-Muller model of hybrid incompatibility**



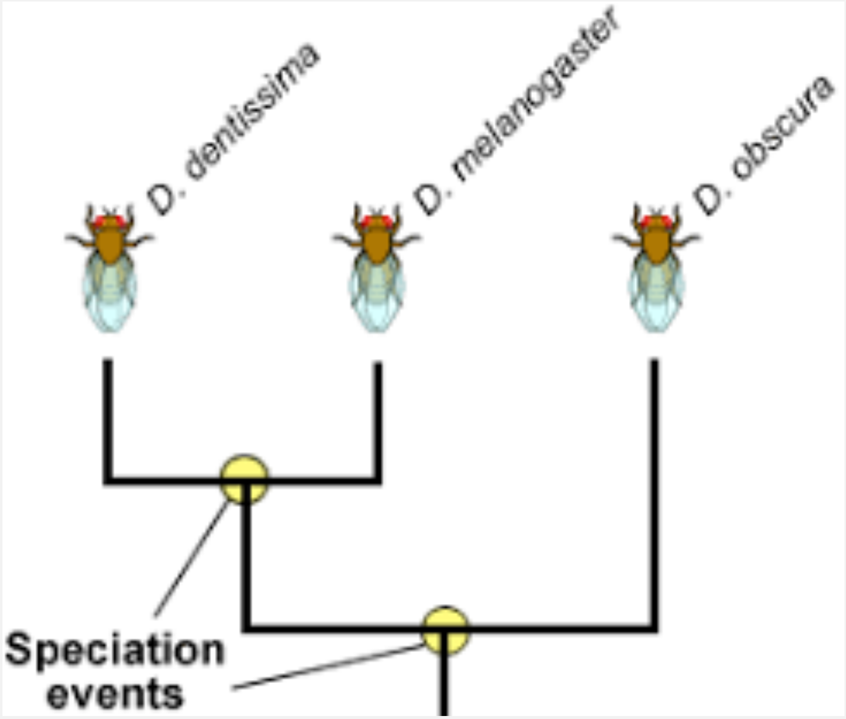
Wu & Ting (2004)

The genomics of speciation

- **The speciation process leads to an increase in the genomic differences between divergent populations.**

➢ Main factors affecting speciation:

- Genetic drift: neutral evolution
- Migration: homogenizing effect
- Selection: adaptive evolution



Simulations

- **Drift, migration and selection**

➢ A biallelic locus evolving in two populations

➢ Equal population size and number of generations

Pop 1: $f(A) = 1$
$f(a) = 0$

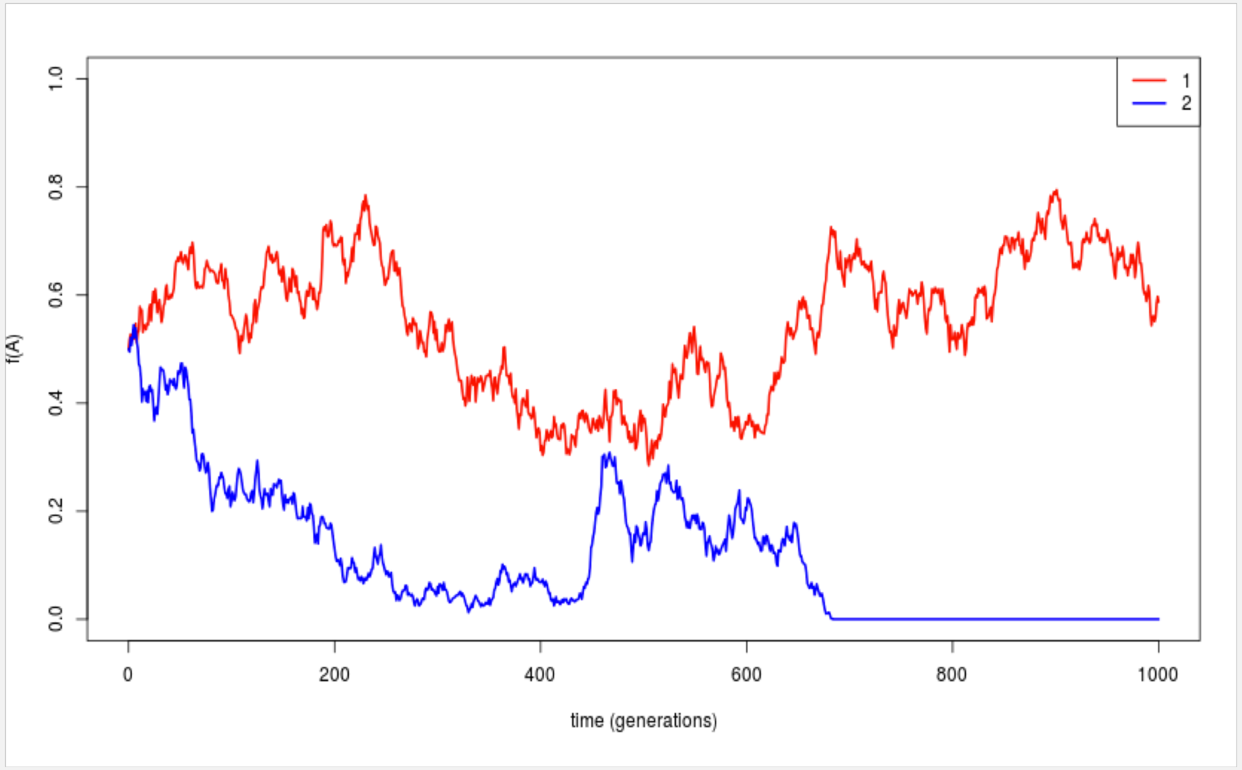
Pop 2: $f(A) = 0$
$f(a) = 1$

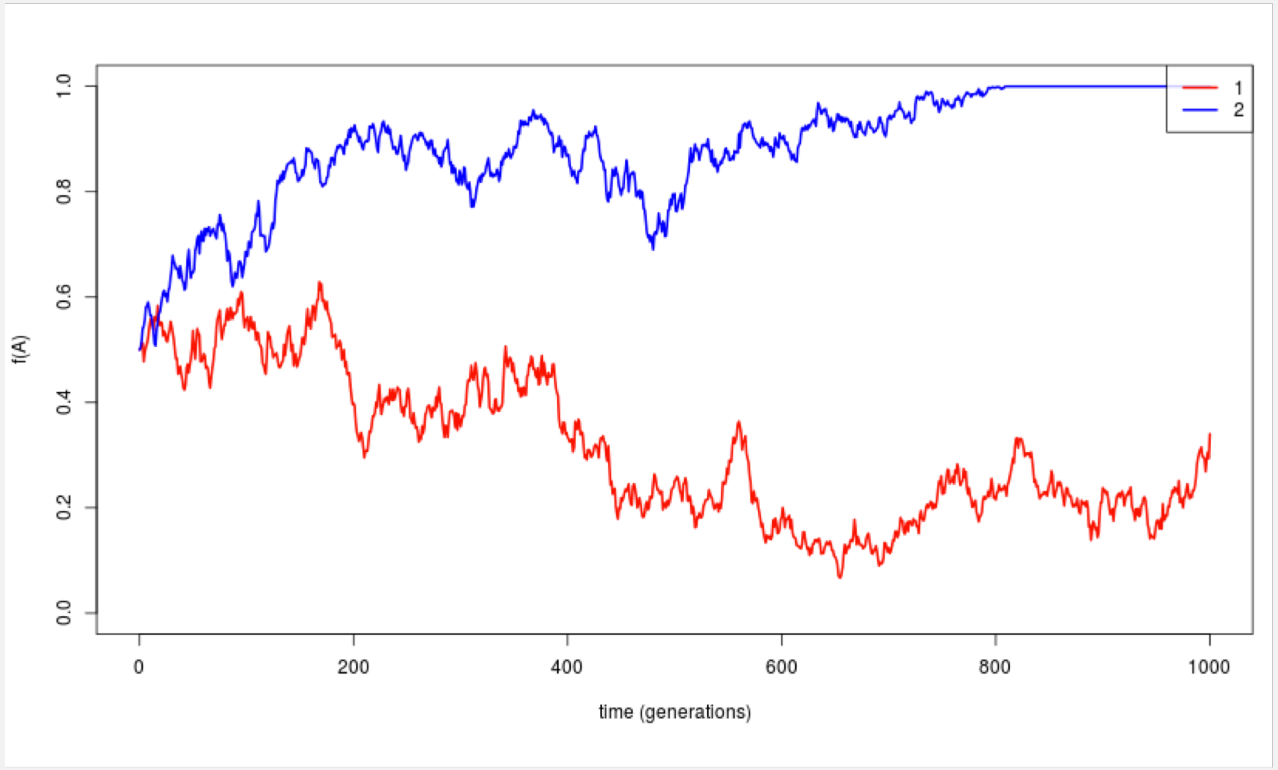
Genetic drift

No selection or migration

Pop 1: **f(A)** = 0.5 f(a) = 0.5

Pop 2: **f(A)** = 0.5 f(a) = 0.5

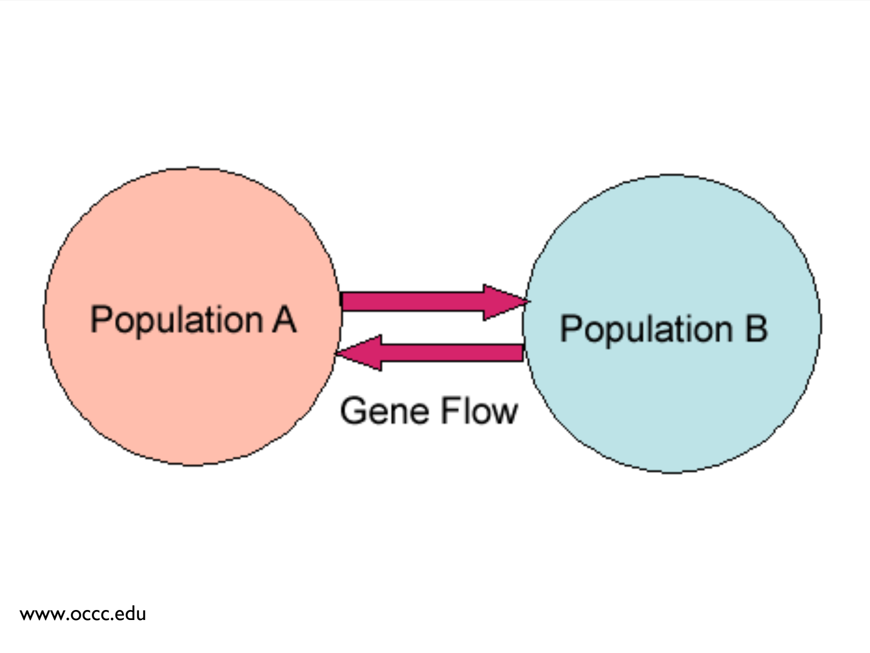


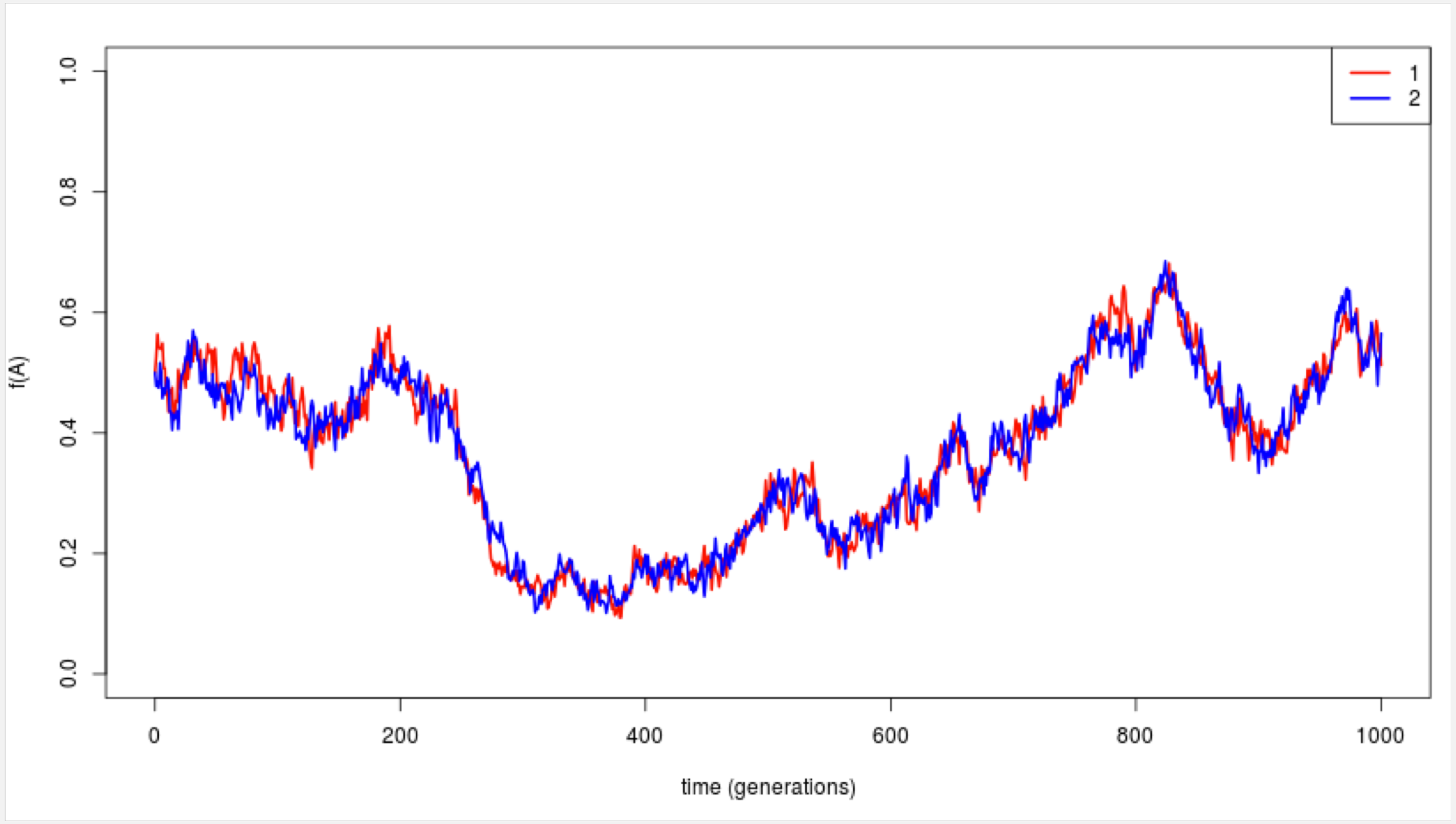


https://phytools.shinyapps.io/migration-selection-drift/

Migration

Equal migration and no selection

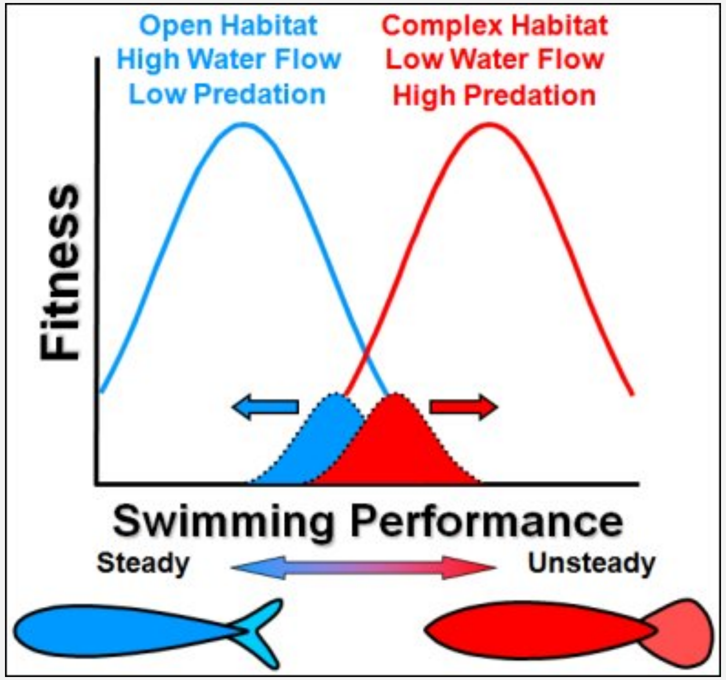




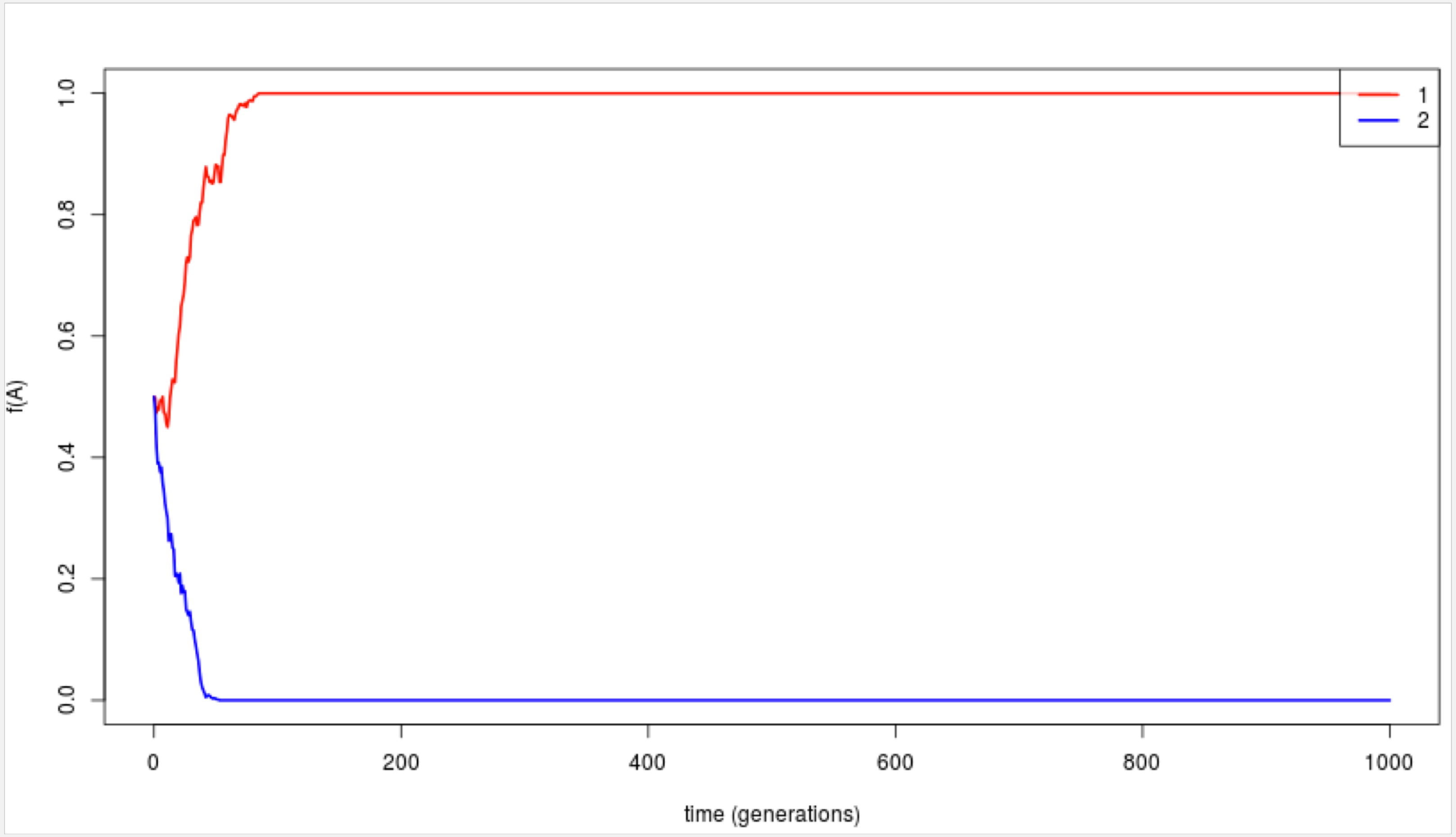
https://phytools.shinyapps.io/migration-selection-drift/

Selection

Divergent selection without migration



http://gambusia.zo.ncsu.edu/locomotion.html

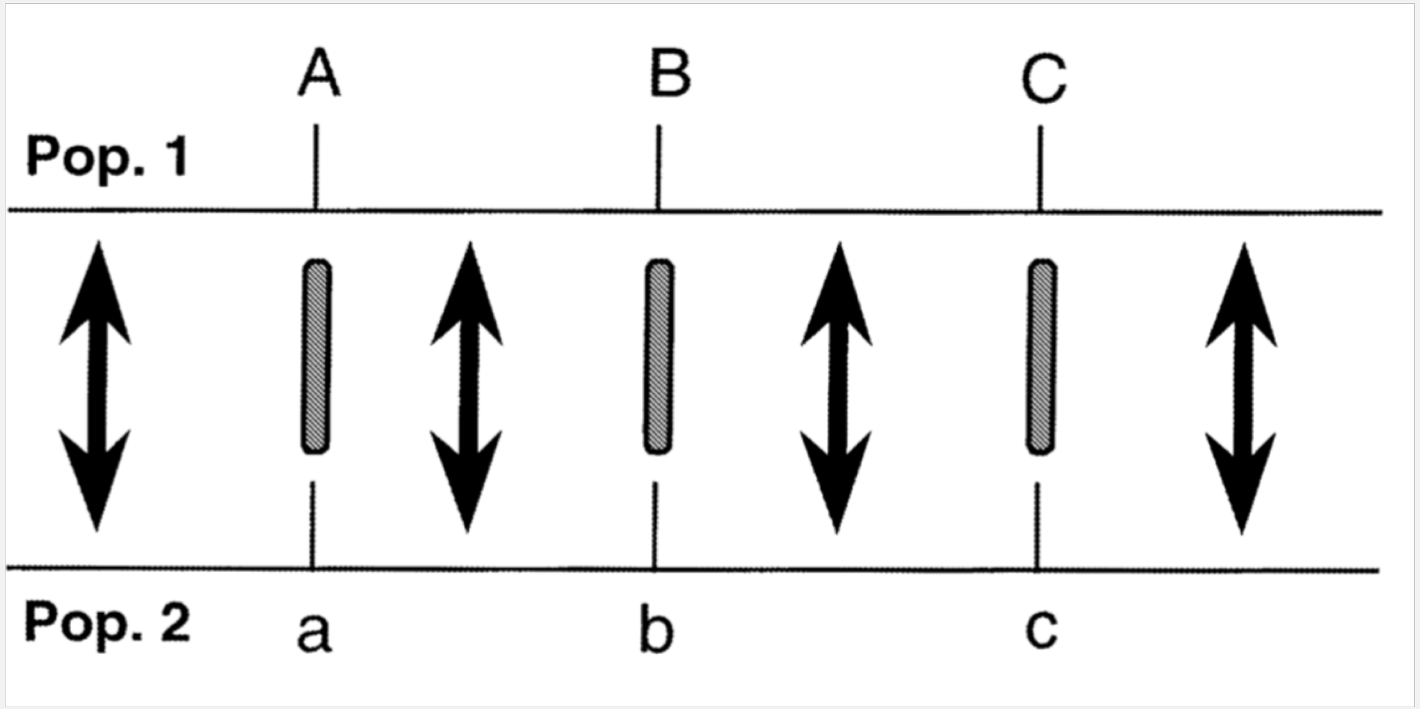


https://phytools.shinyapps.io/migration-selection-drift/

Genomics of speciation

Four-Phase model:

1. Direct divergent selection (DS)

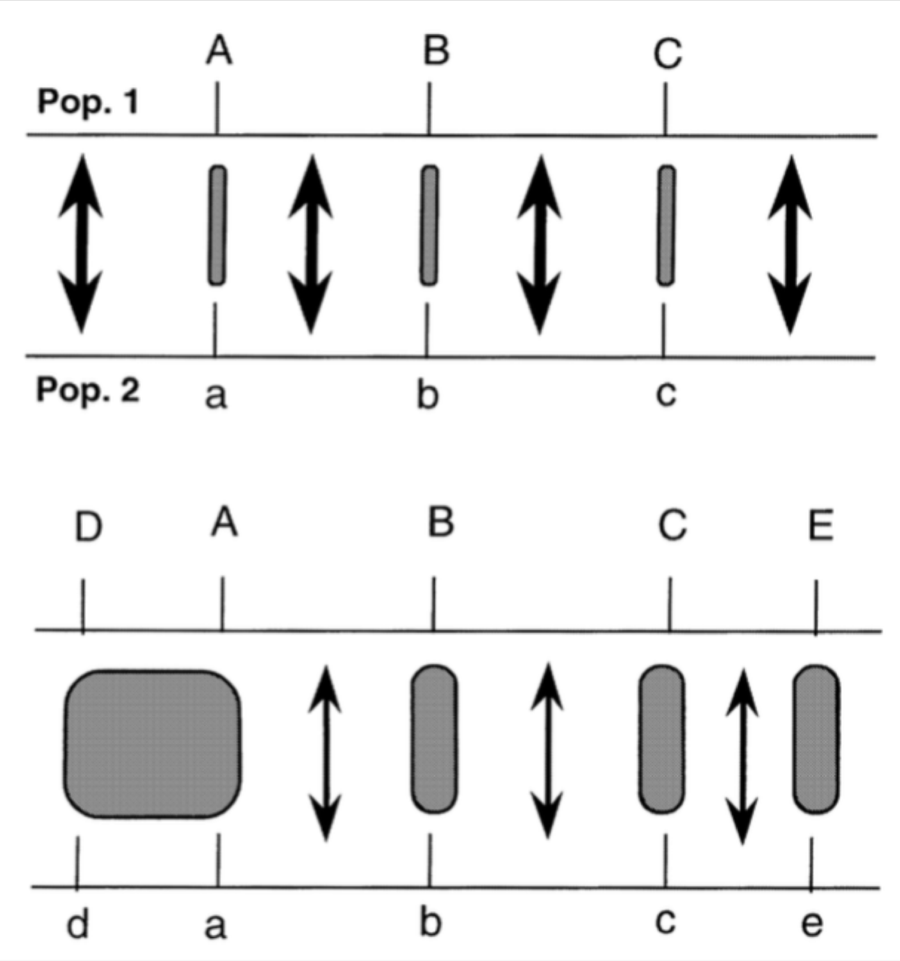


Wu (2001) *J. Evol. Biol.*

Genomics of speciation

Four-Phase model:

1. Direct divergent selection (DS)
2. Divergence hitchhiking (DH)

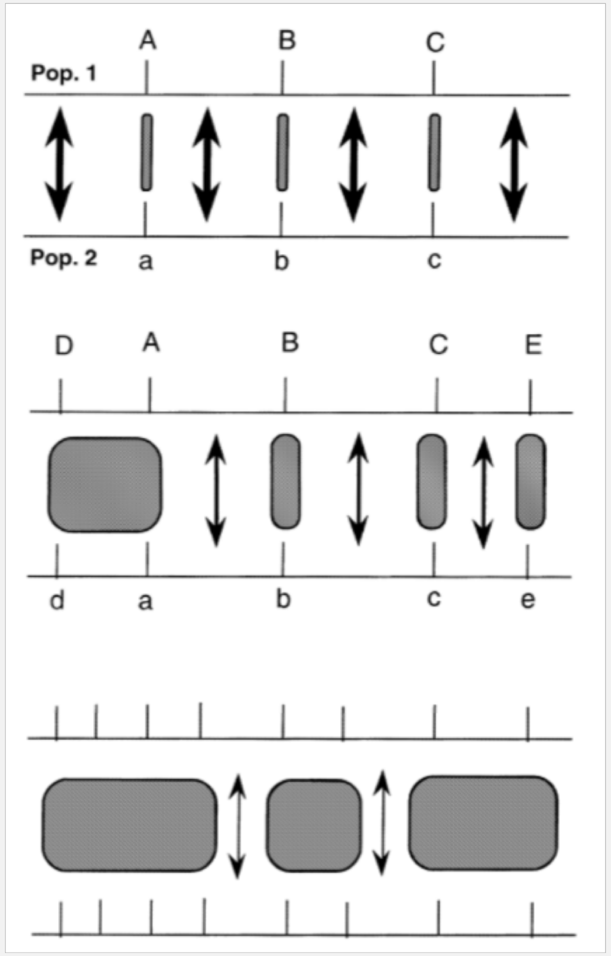


Wu (2001) *J. Evol. Biol.*

Genomics of speciation

Four-Phase model:

1. Direct divergent selection (DS)
2. Divergence hitchhiking (DH)
3. Genome hitchhiking (GH)

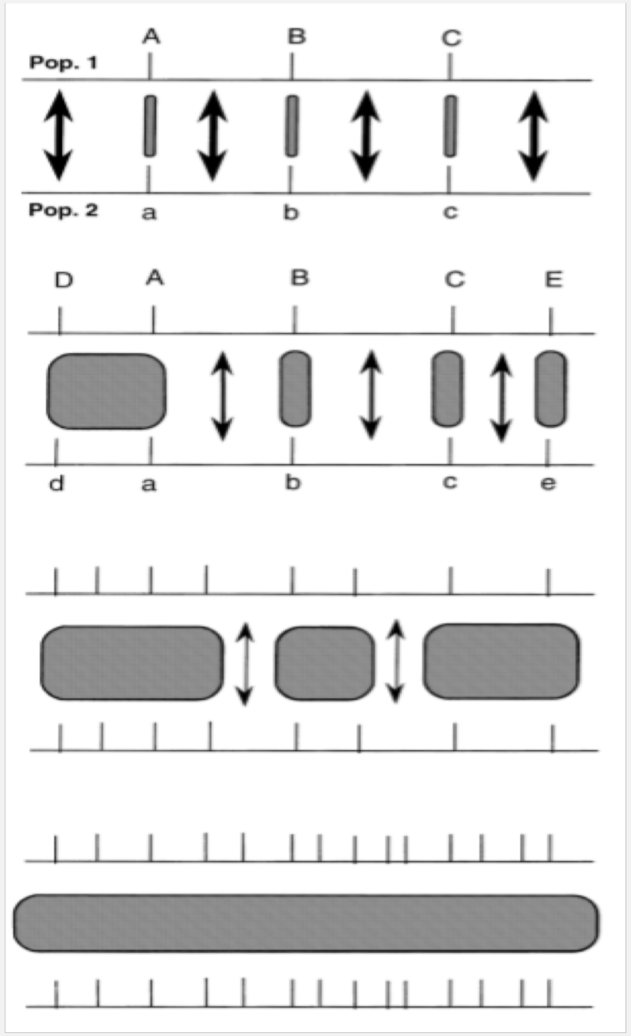


Wu (2001) *J. Evol. Biol.*

Genomics of speciation

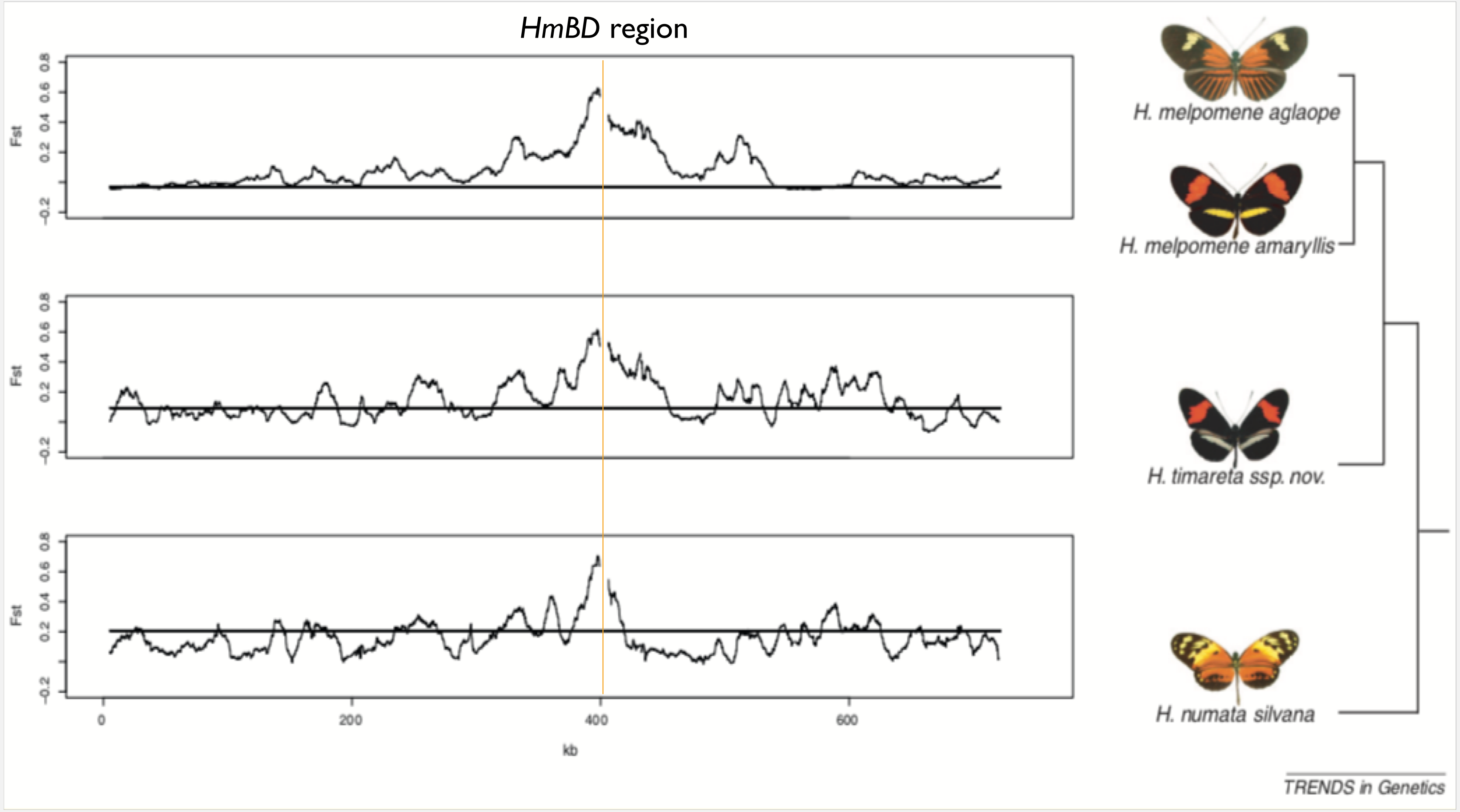
Four-Phase model:

1. Direct divergent selection (DS)
2. Divergence hitchhiking (DH)
3. Genome hitchhiking (GH)
4. Speciation divergence



Wu (2001) *J. Evol. Biol.*

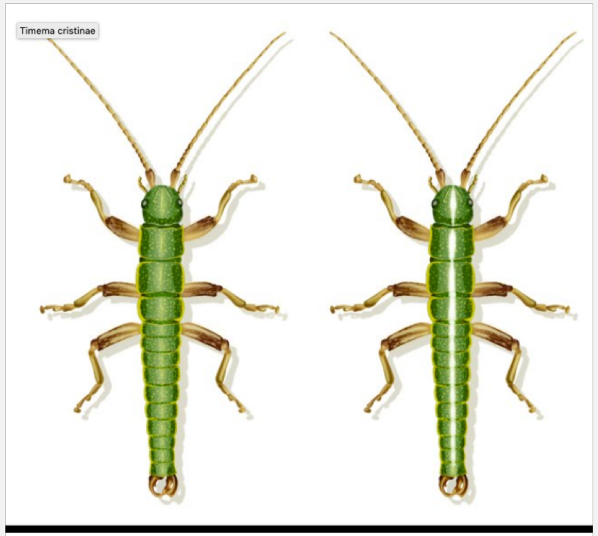
Genomic divergence



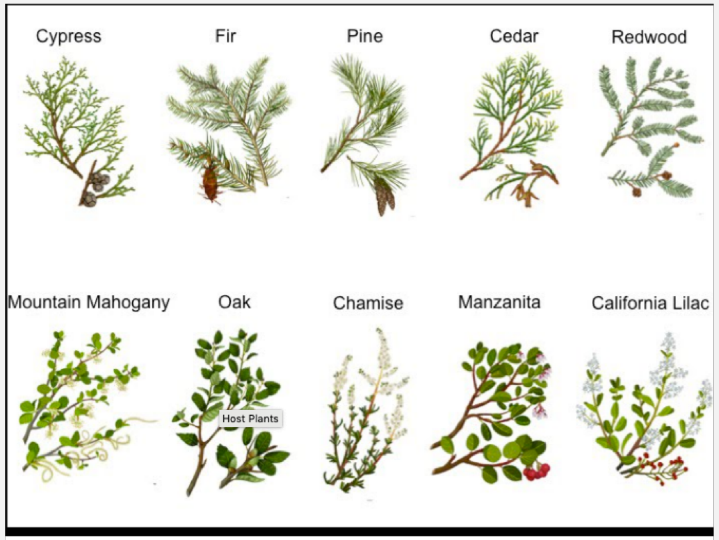
Feder et al. (2012) *J.*

Genomic divergence

Genus *Timema*



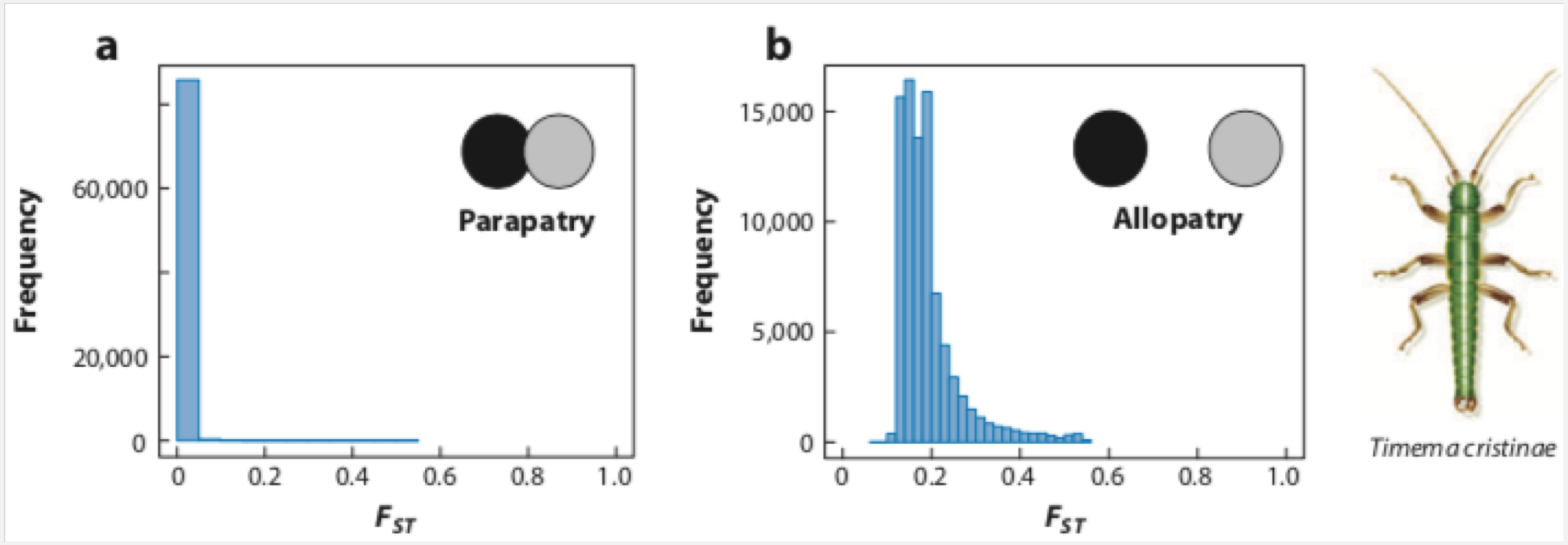
Male Timema cristinae: green morph (left) and green-striped morph (right; illustration by Rosa Ribas).



Some of the host plants used by Timema spp. (illustration by Rosa Ribas).

https://pure.royalholloway.ac.uk/portal/en/persons/rudiger-riesch(3ad55f25-7f78-4a47-b722-af0b845939b1).html

Genomic divergence

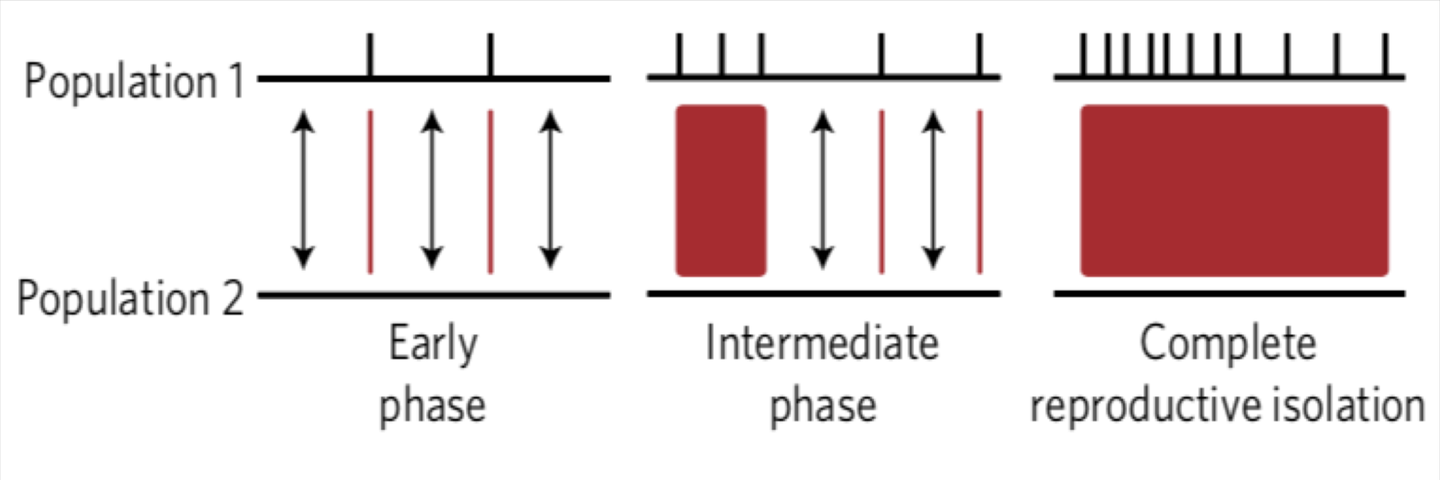


Feder et al. (2013), *Annu. Rev. Ecol. Evol. Syst.*

Phylogenetics

- Allele frequencies: within species

- New character states (mutations): between species



Riesch (2017) *Nature*

Phylogenetics

- Ancestral Pop

1. GGG**T**
2. GGG**T**
3. GGG**C**
4. GGG**C**

- New sp. I

1. GGG**T**
2. GGG**T**
3. GGG**T**
4. GGG**T**

Fst = 1

- New sp. 2

1. GGG**C**
2. GGG**C**
3. GGG**C**
4. GGG**C**

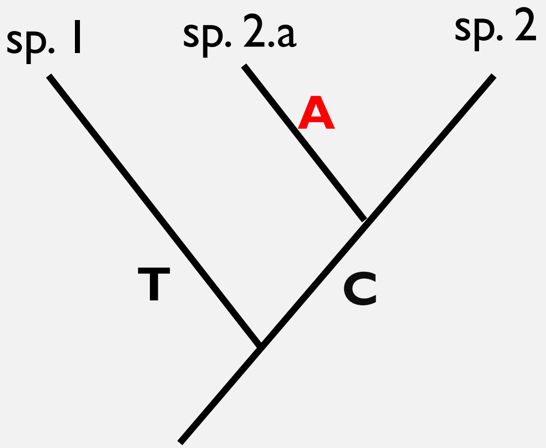
- New pop 2

1. GGG**A**
2. GGG**C**
3. GGG**C**
4. GGG**C**

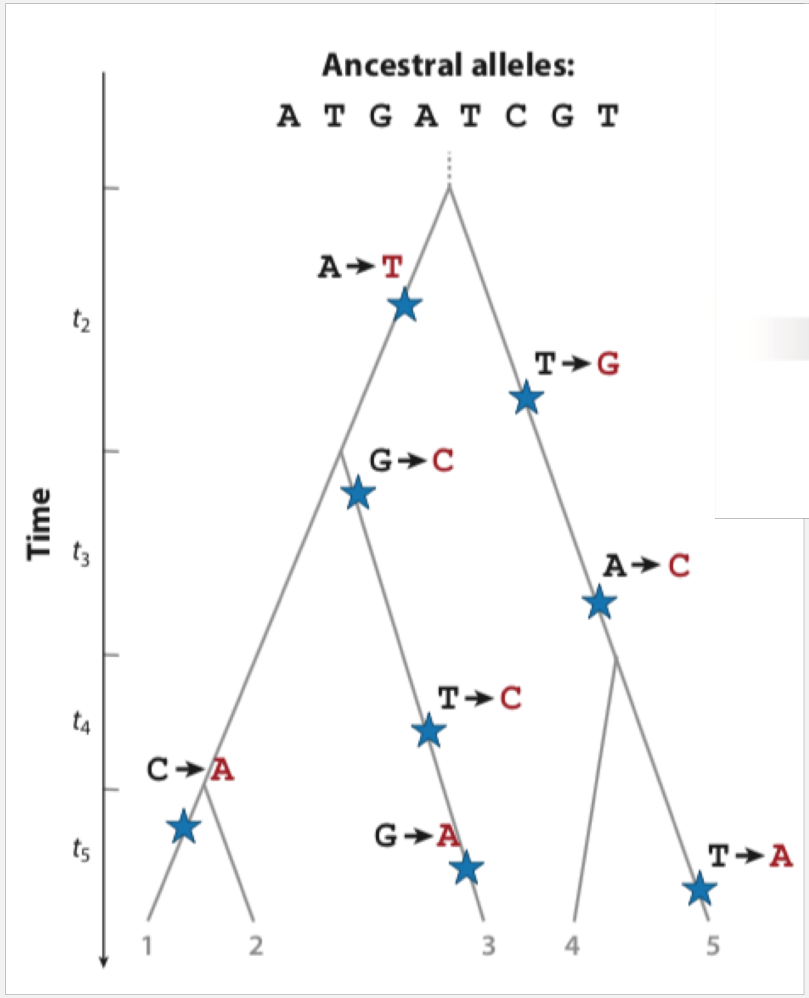
- New sp 2. a

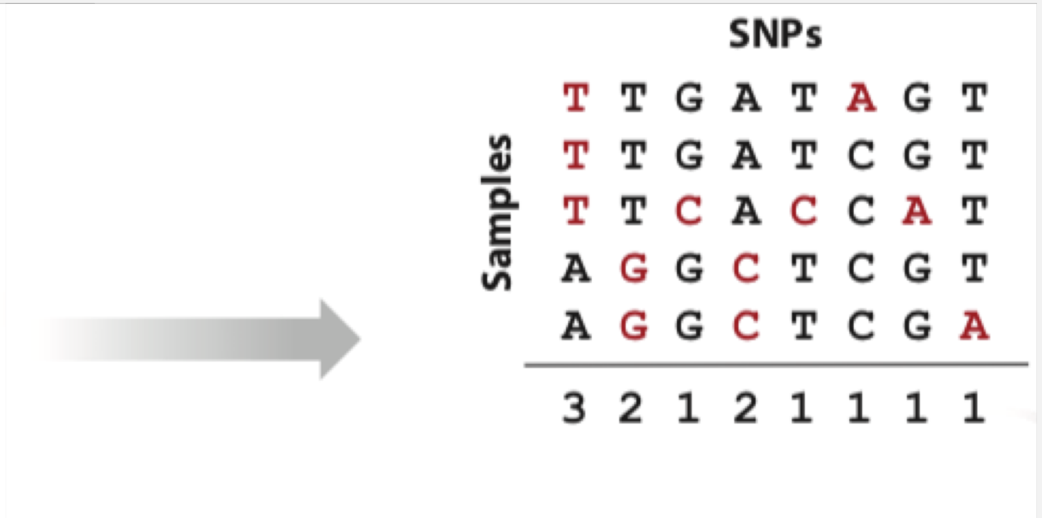
1. GGG**A**
2. GGG**A**
3. GGG**A**
4. GGG**A**

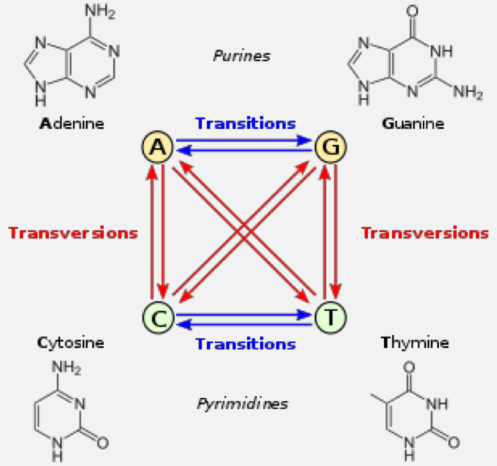
sp. I GGG**T**
sp 2 GGG**C**
sp 2.a GGG**A**



Phylogenetics

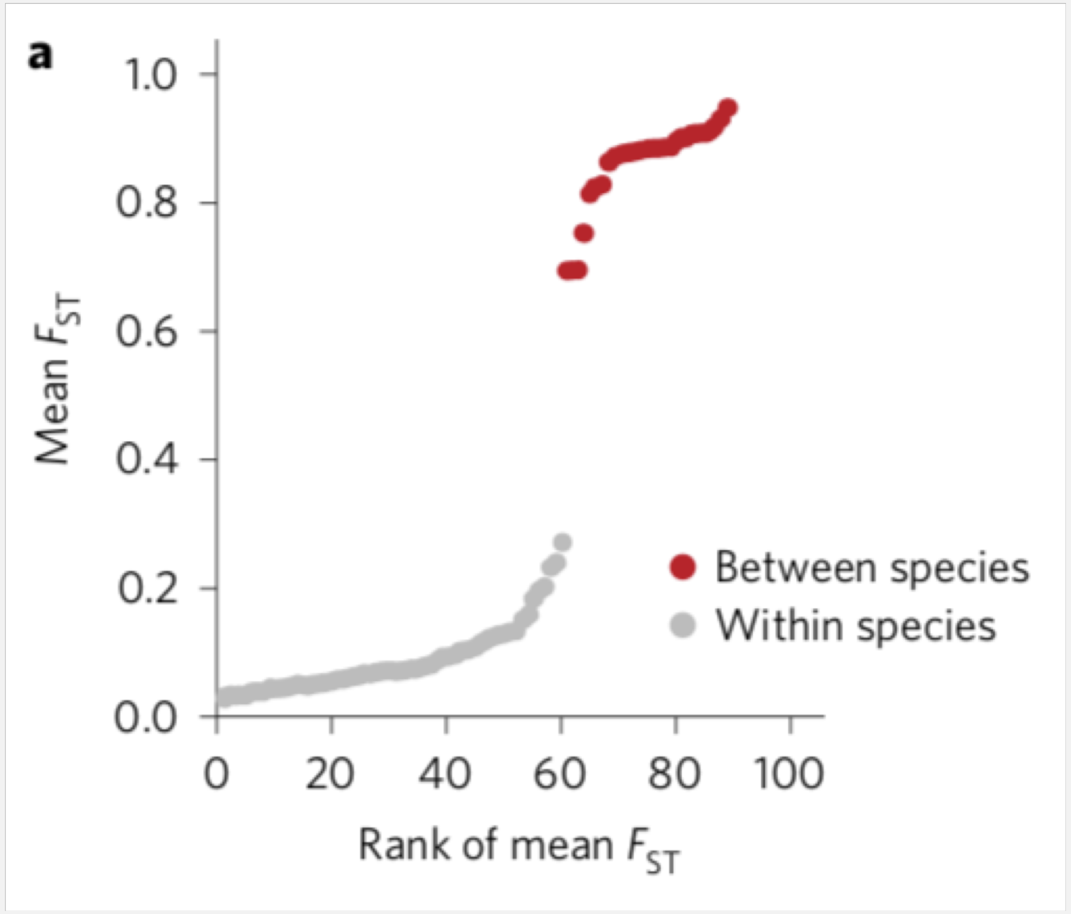


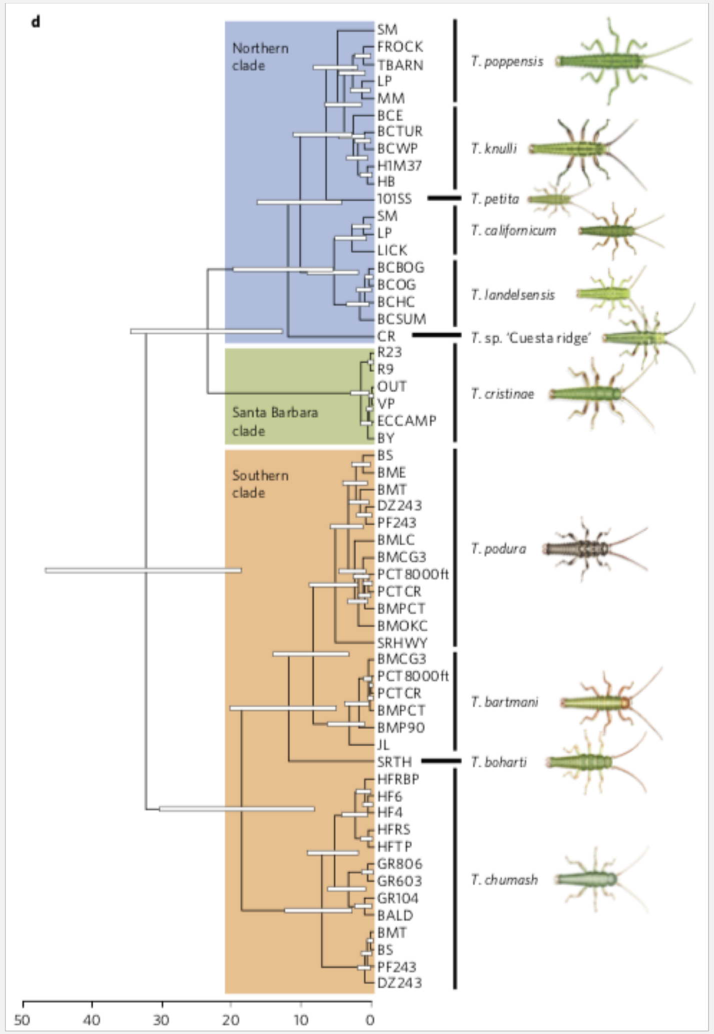




Lohmueller (2018) *Annual Reviews*

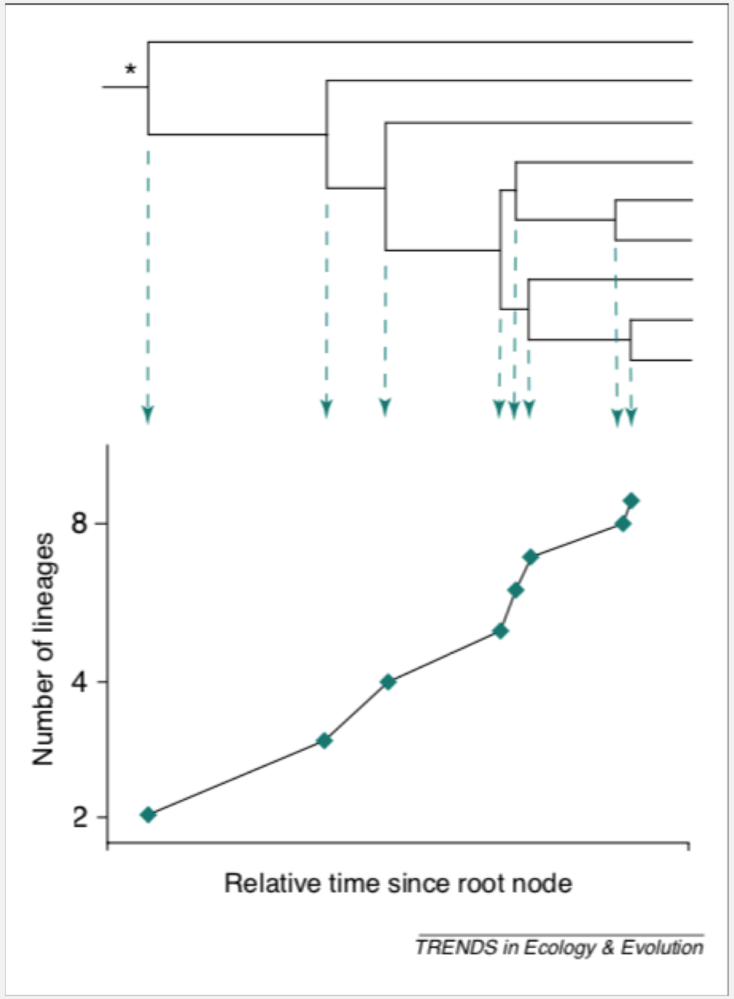
Phylogenetics



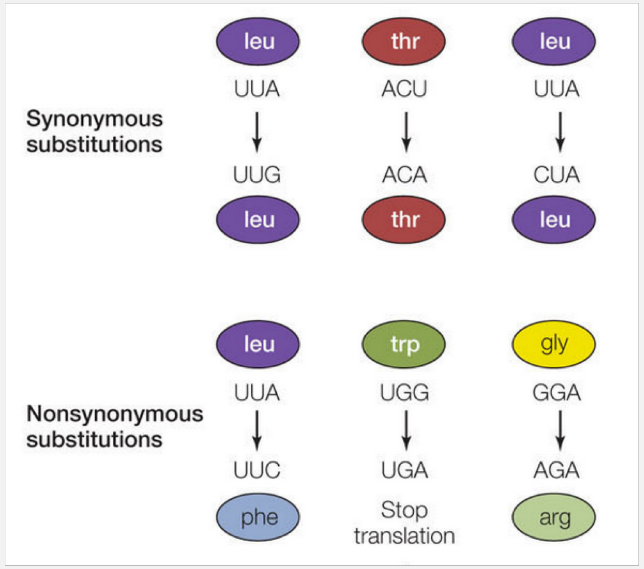


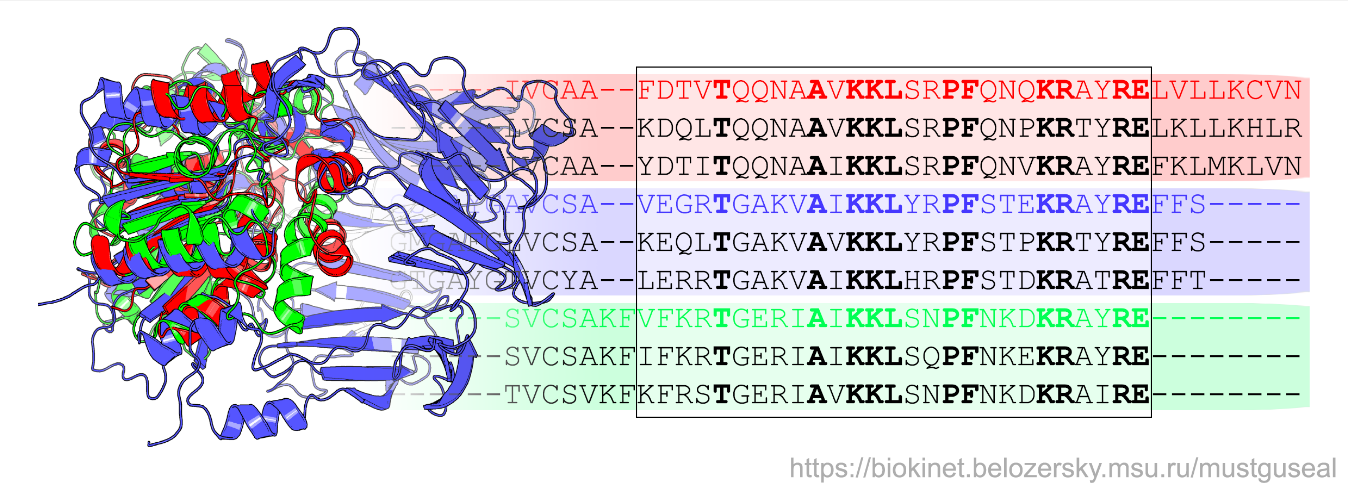
Riesch (2017) *Nature*

Phylogenetics



Barraclough & Sean Nee (2001)



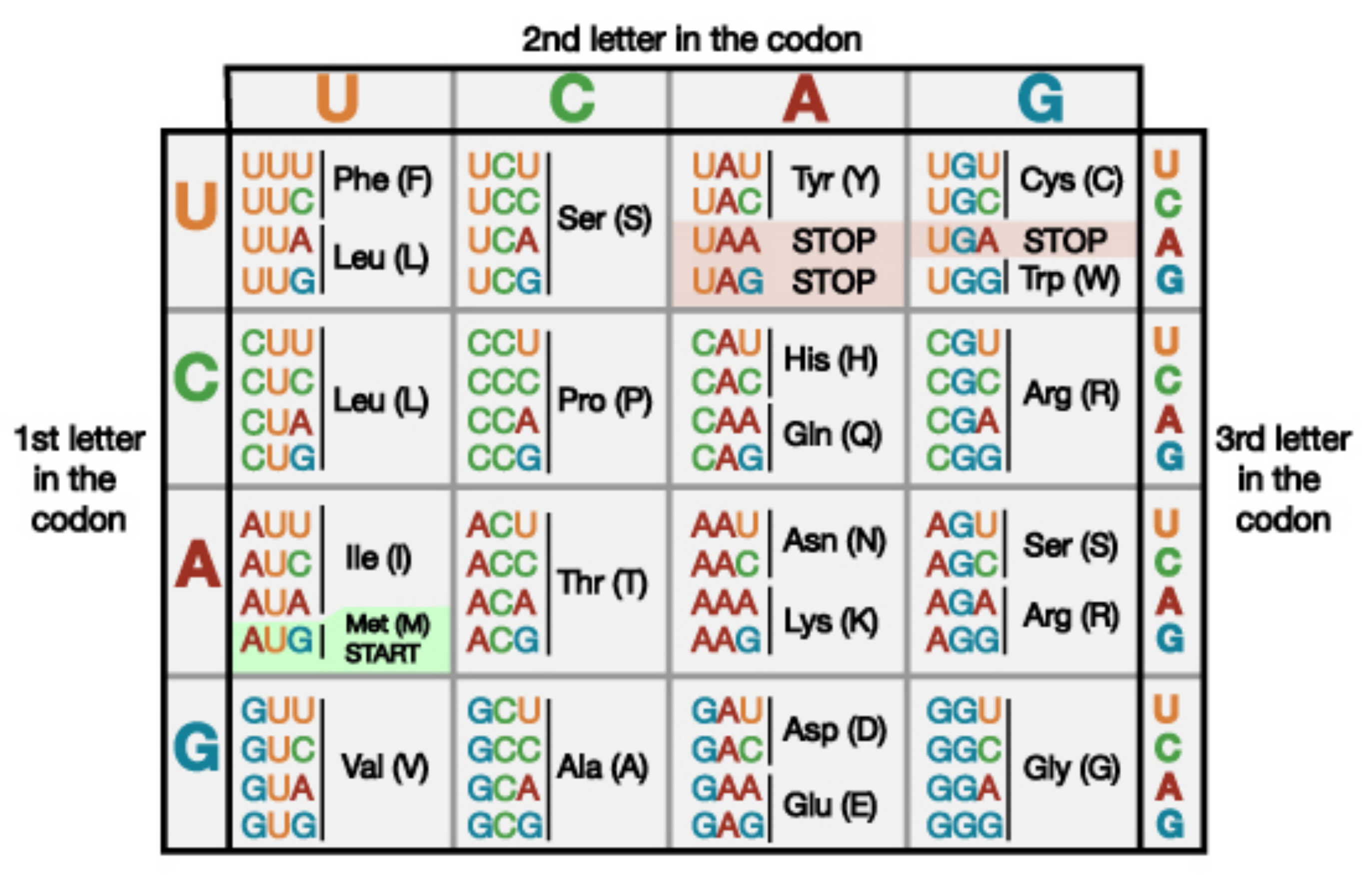


Phylogenetics

- **Synonymous vs non-synonymous**
- **dN/dS ratio**

dN = number of non-synonymous changes **per non-synonymous site**

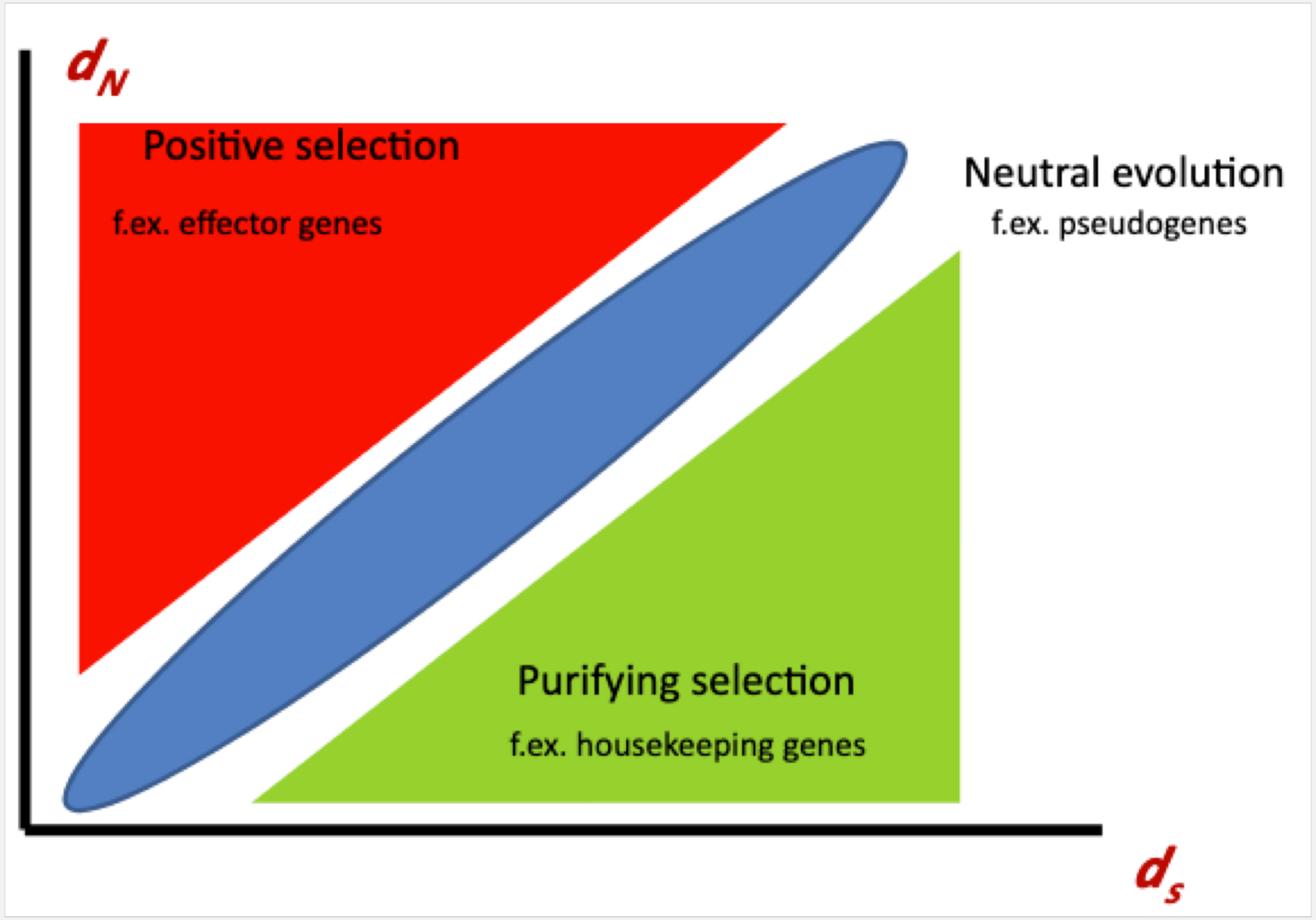
dS = number of synonymous changes **per synonymous site**



Phylogenetics

Synonymous vs non-synonymous

- dN/dS = 1
  Neutral selection
- dN/dS < 1
  Negative selection
- dN/dS > 1
  Positive selection

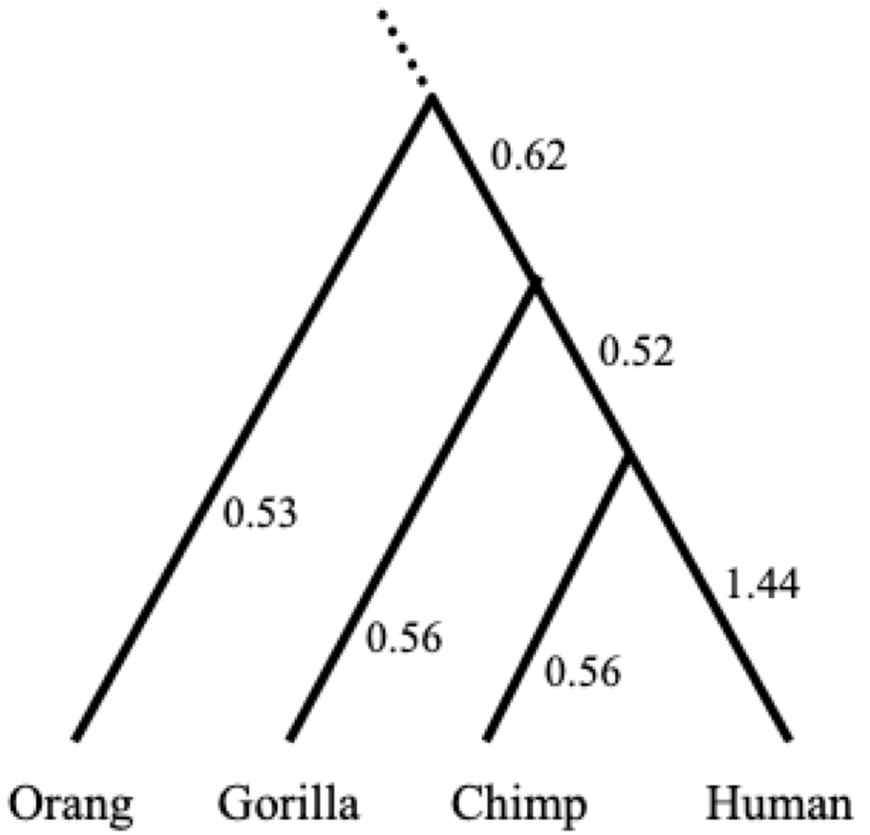


https://slideplayer.com/slide/2353953/

Phylogenetics

Synonymous vs non-synonymous

- *ASPM* gene
- Brain size



Human-specific increase in *d*N/*d*S ratio (P<0.03)

Evans et al (2004) *Hum. Mol. Genet*

Discussion papers

HYBRID SPECIATION

Rapid hybrid speciation in Darwin's finches

Sangeet Lamichhaney,[1*] Fan Han,[1] Matthew T. Webster,[1] Leif Andersson,[1,2,3†]
B. Rosemary Grant,[4] Peter R. Grant[4]

RESEARCH ARTICLE

Multispecies Outcomes of Sympatric Speciation after Admixture with the Source Population in Two Radiations of Nicaraguan Crater Lake Cichlids

Andreas F. Kautt, Gonzalo Machado-Schiaffino, Axel Meyer*

Department of Biology, University of Konstanz, Konstanz, Baden-Württemberg, Germany