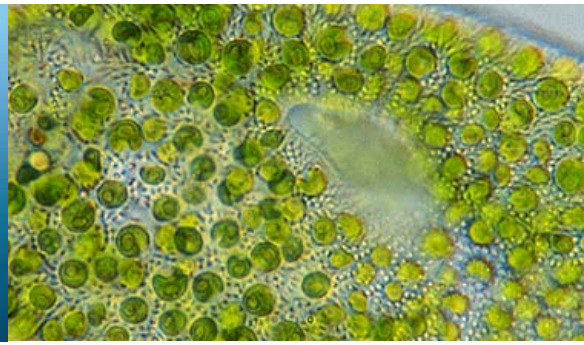
Complexity of evolutionary process helps maintain genetic variation

Patrik Nosil

Genetic variation is the fuel for evolution



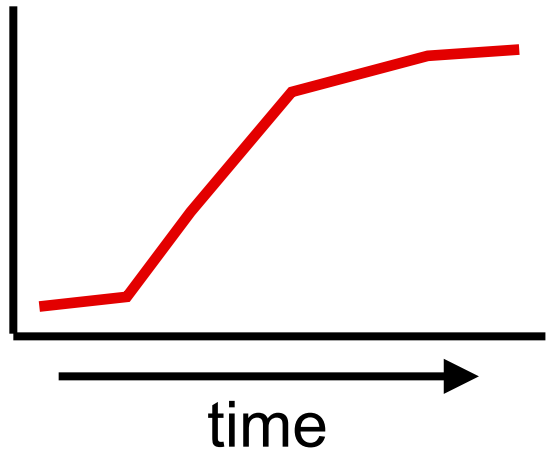




Many forms of selection and random drift deplete genetic variation

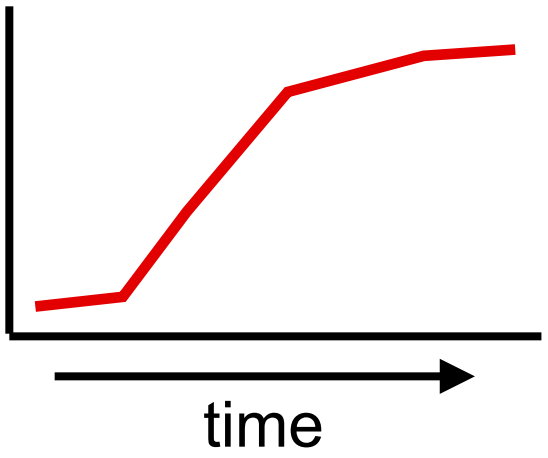
So, how is variation maintained over long-time periods?

Directional evolution

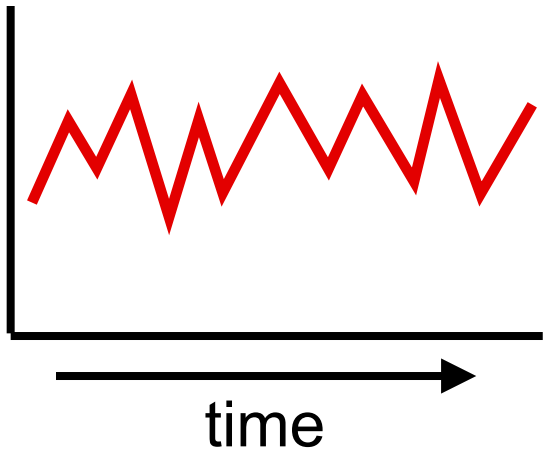
(transient variation)



Directional evolution
(transient variation)



Fluctuating evolution
(balancing selection)



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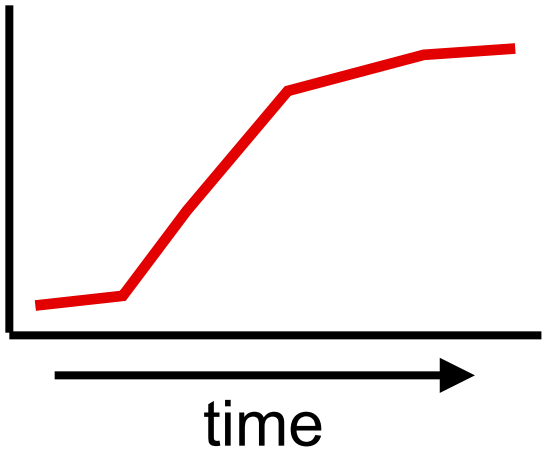

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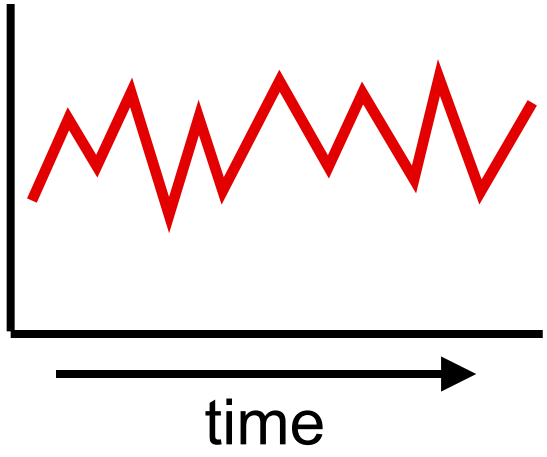
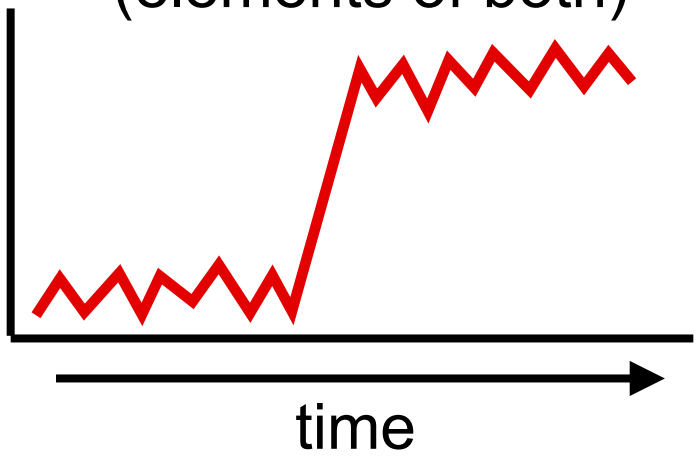


Simpson's adaptive zones
(elements of both)



1) *Timema* stick insect system

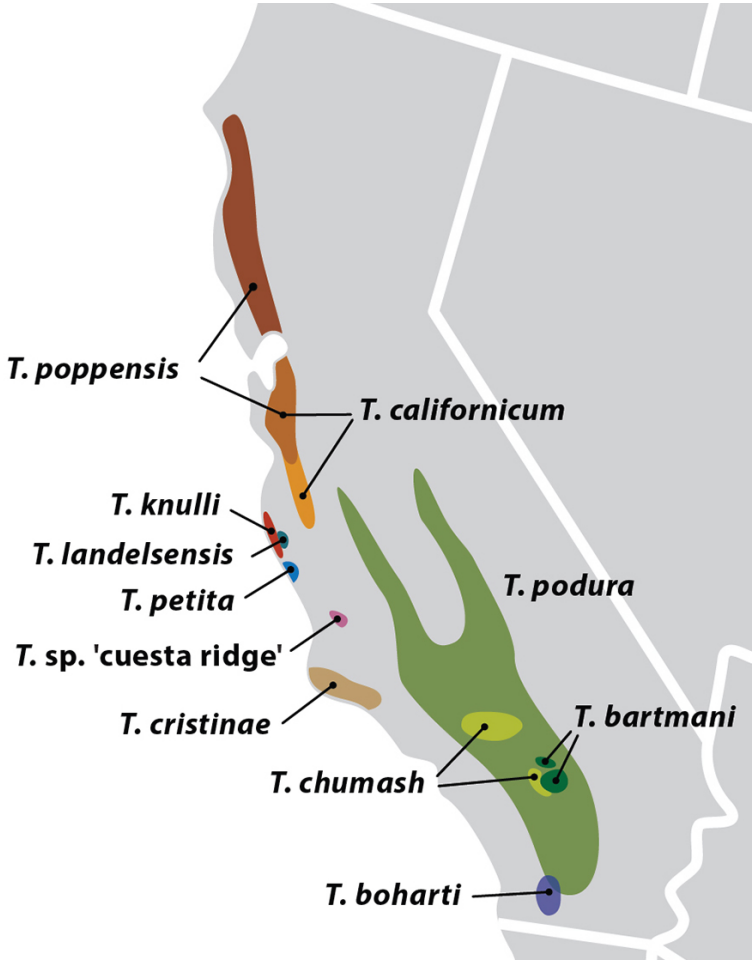
2) Maintaining genomic variation for diet

3) Evolution of host preference

Zach Gompert


M. Muschick photo

Multiple species across California



Riesch *et al.* 2017 *Nature EE*


A. Comeault photo

A. Comeault photo

Rely on crypsis for survival against visual predators

Nosil and Crespi 2006 *PNAS*

R. Villoutreix photo


M. Muschick photo

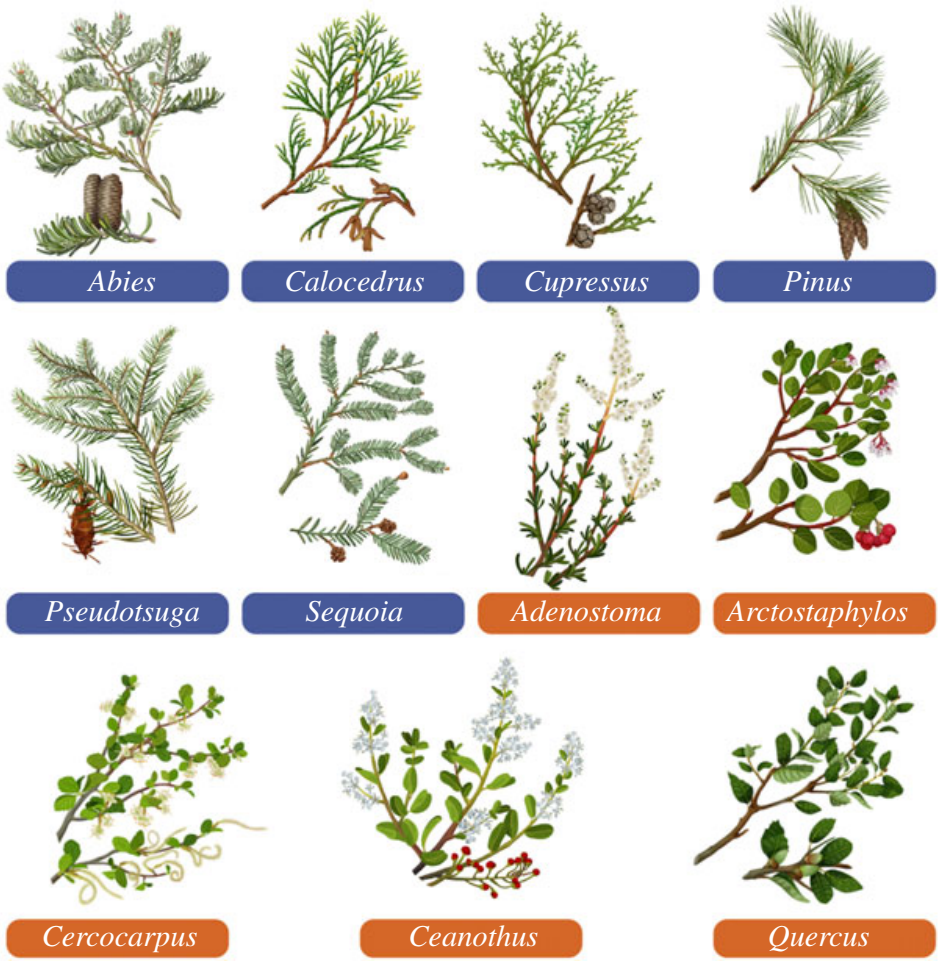
M. Muschick photo

A. Comeault photo

M. Muschick photo

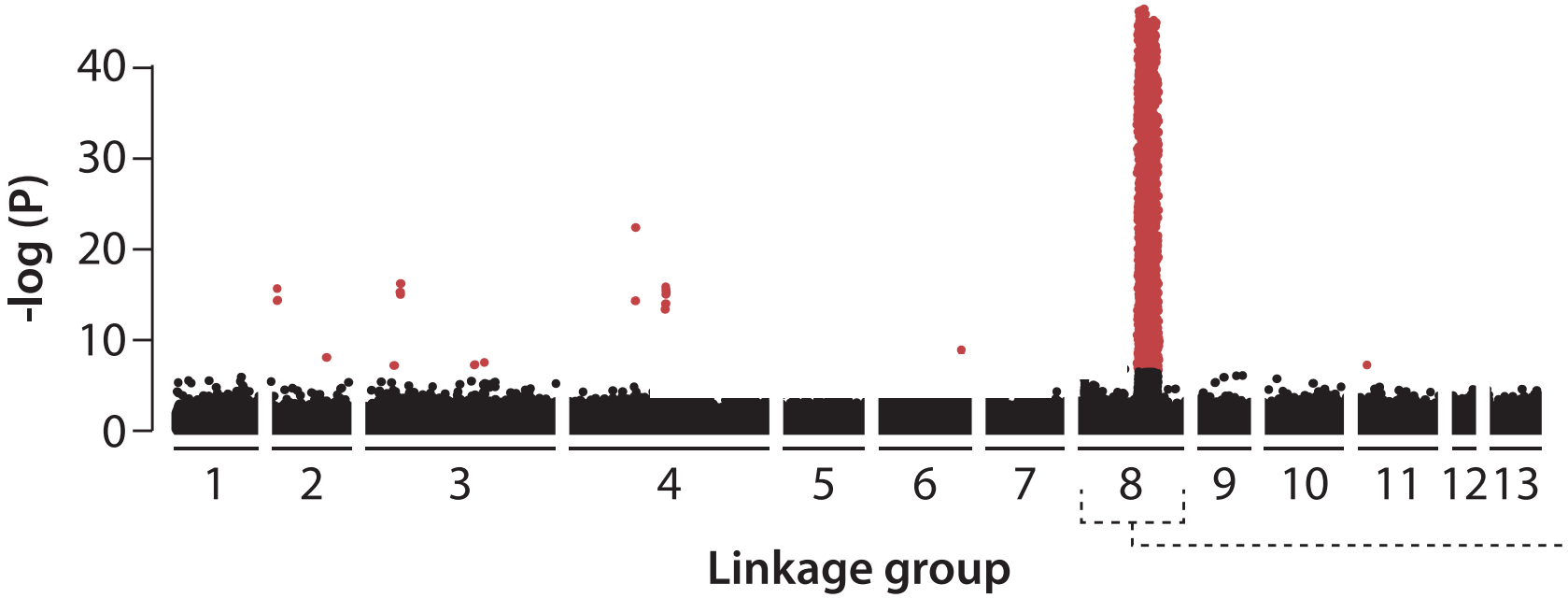
M. Muschick photo

Timema use a wide range of host plants in their diet



Muschick *et al.* 2020 *Phil Trans B*

Multiple reference genomes



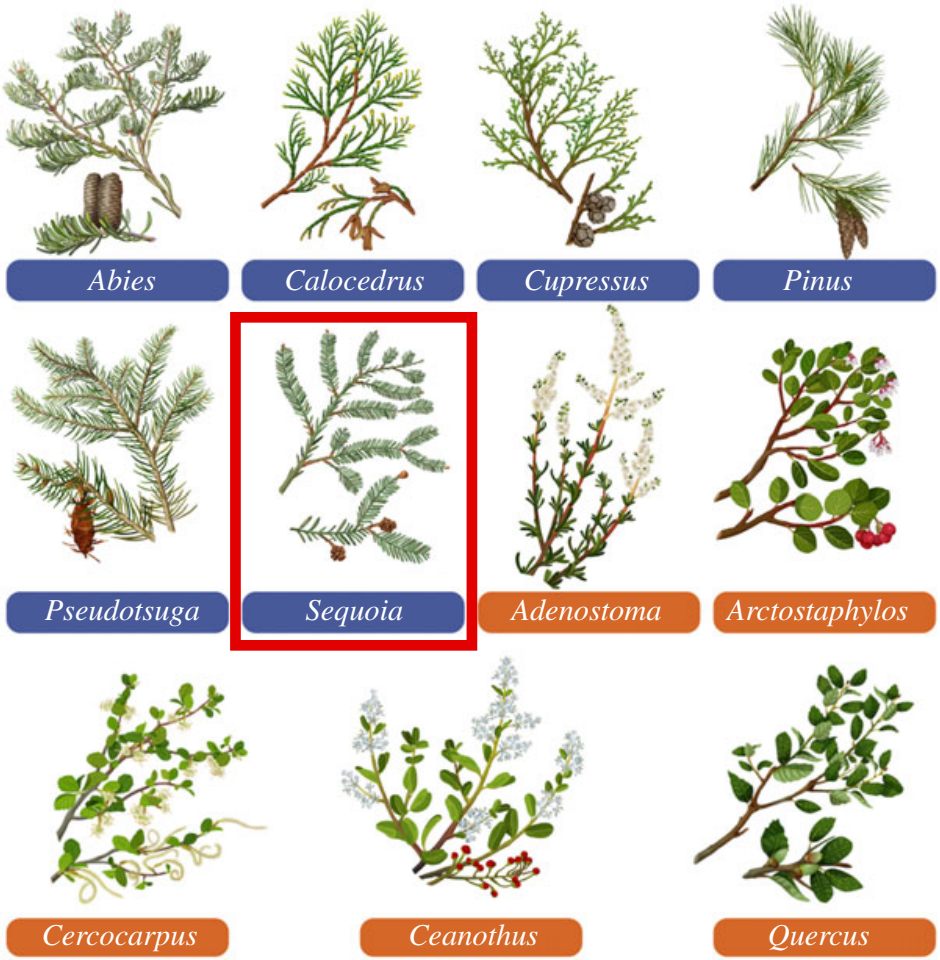
Soria-Corrasco *et al.* 2014 *Science*
Nosil *et al.* 2018 *Science*
Villoutreix *et al.* 2021 *Science*

1) *Timema* stick insect system

2) Maintaining genomic variation for diet

3) Evolution of host preference

Redwood is a particularly challenging host



Larose *et al.* 2020 *Ecology Letters*

Complexity of evolutionary process provides resilience against loss of genetic variation

Patrik Nosil
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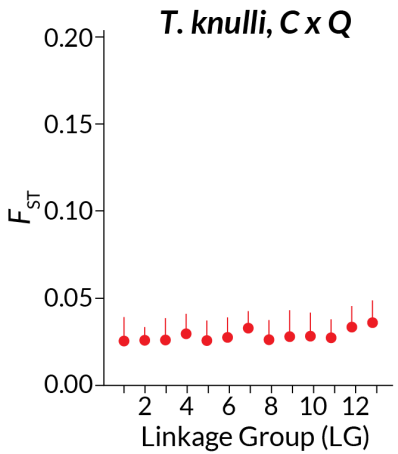
1) Genetic scan

2) Compare independent genome assemblies

3) Experimental analysis of fitness

4) Modeling of allele-frequency variation

Strong genetic differentiation restricted to one LG in RW feeding comparisons



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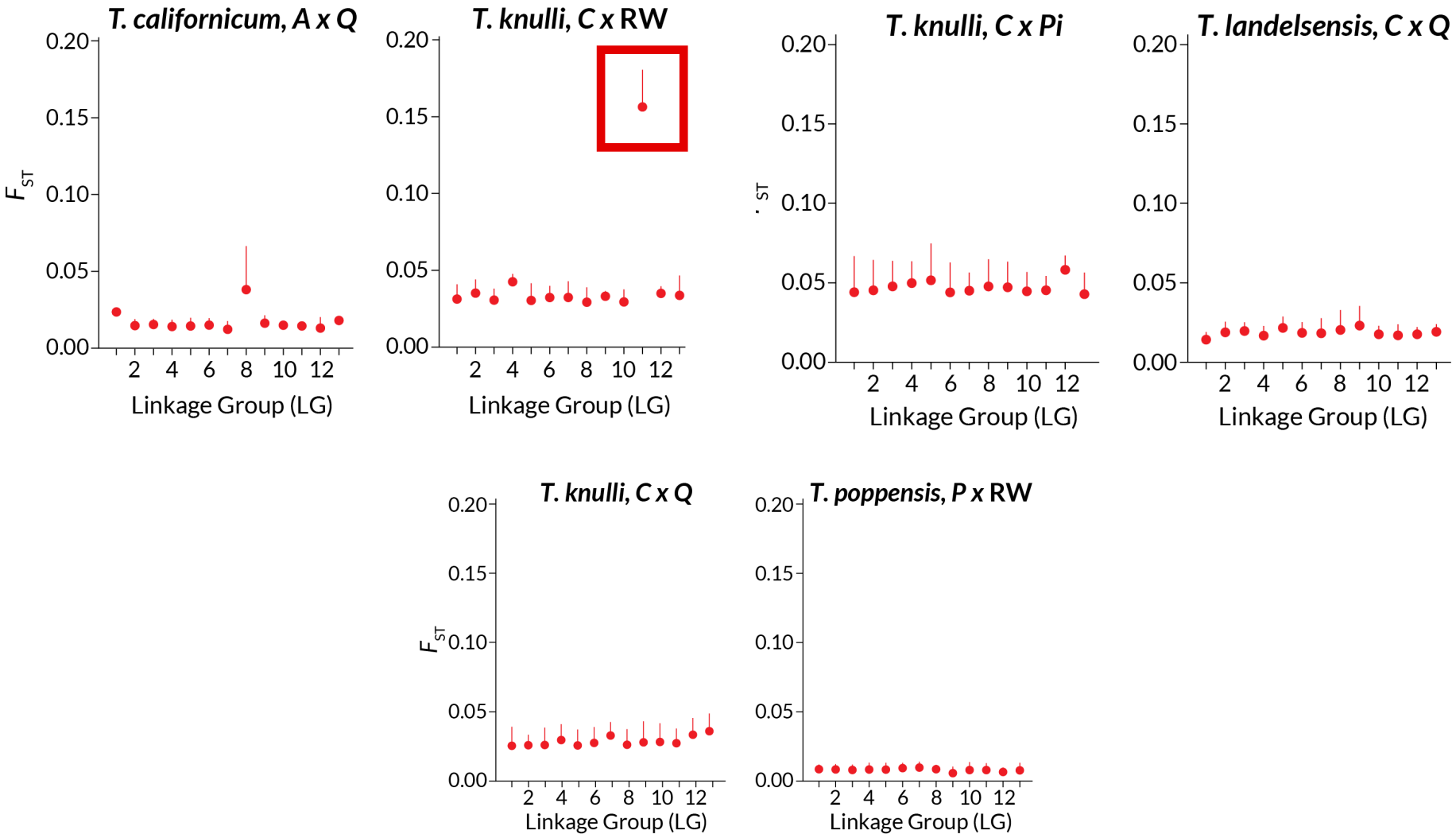
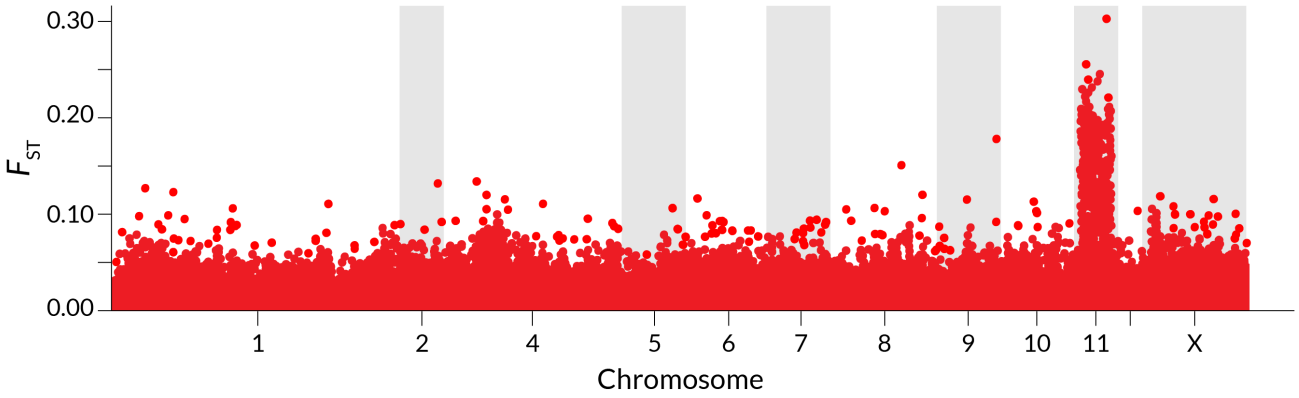


Studied Redwood and *Ceanothus* feeding populations

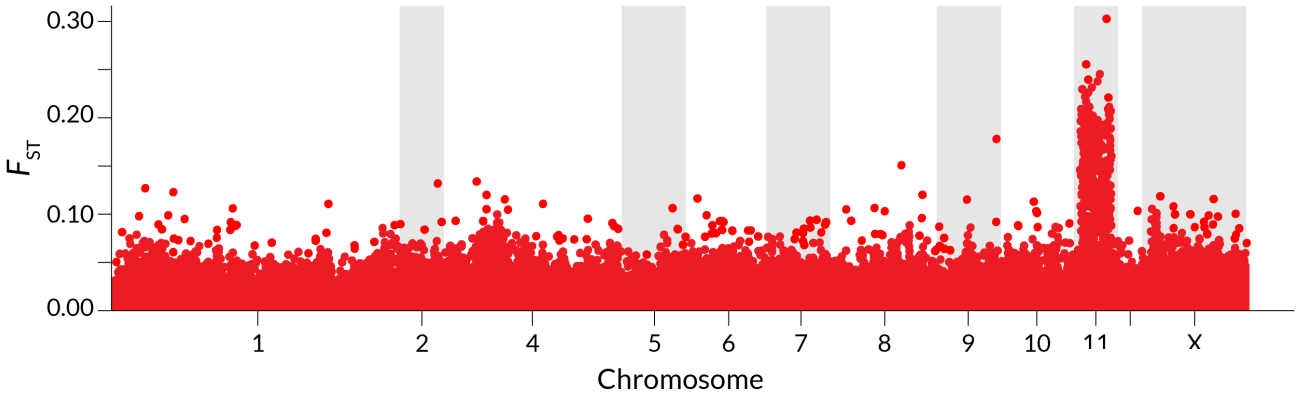
Sequoia

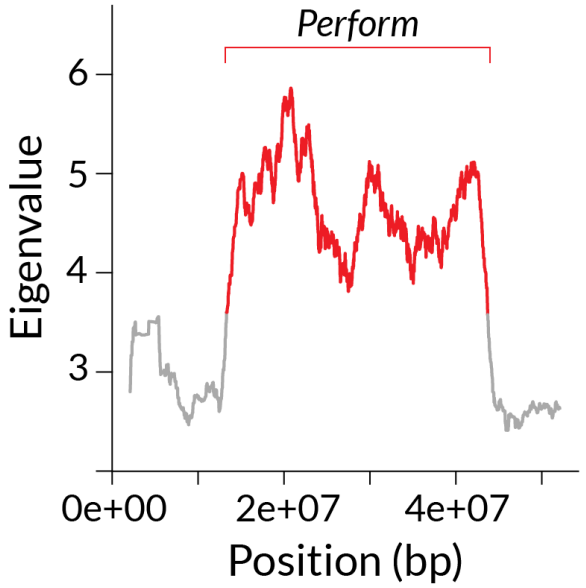
Ceanothus

Delimited the *Perform* locus and studied its evolution

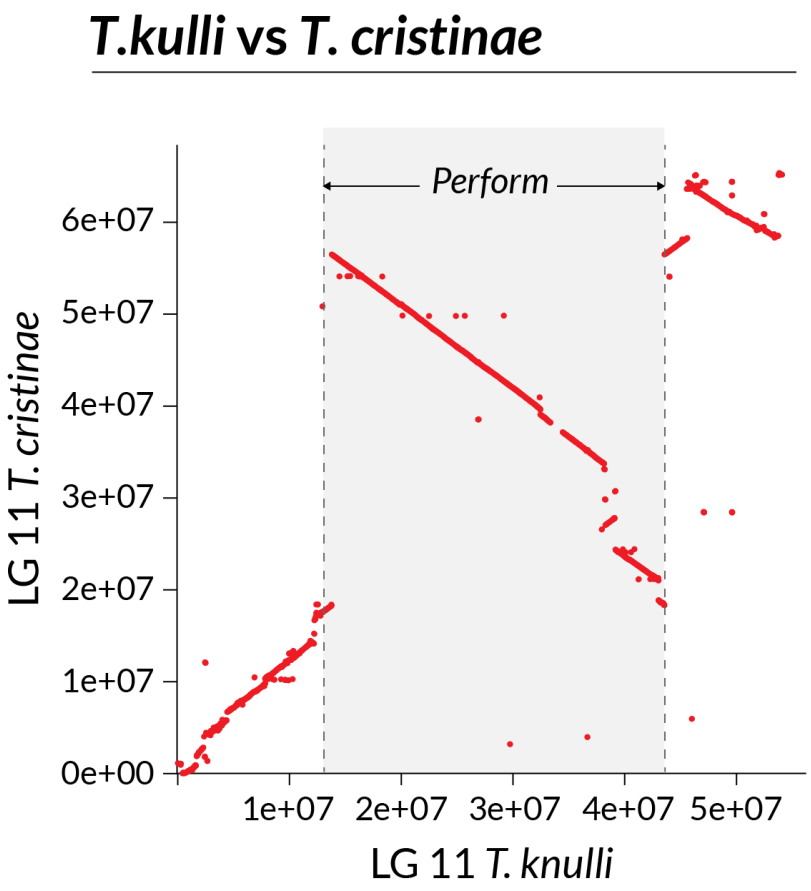


Delimited the *Perform* locus and studied its evolution



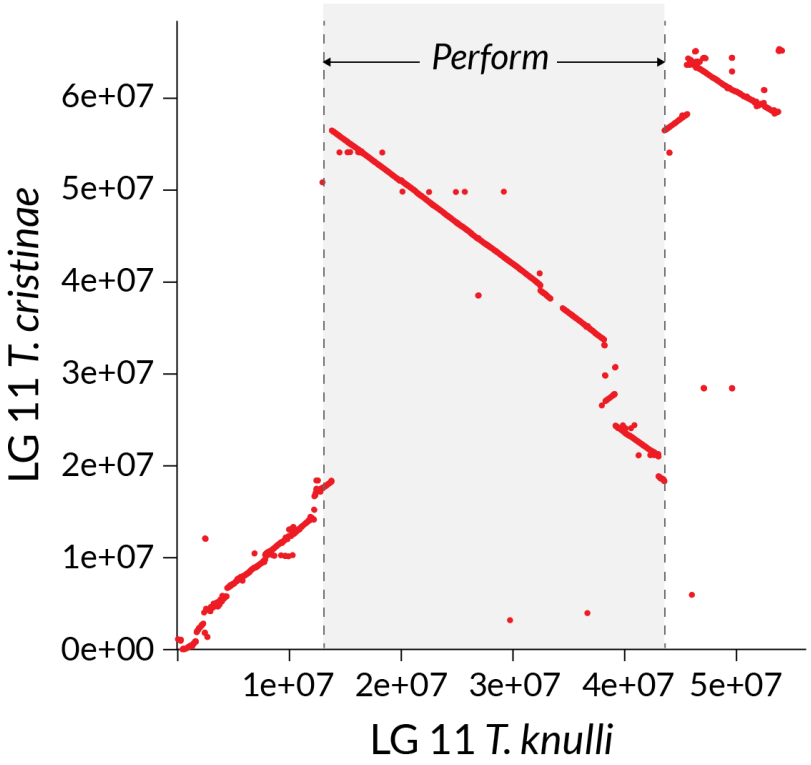


Perform is an ancient (~5-10 MYA) chromosomal inversion

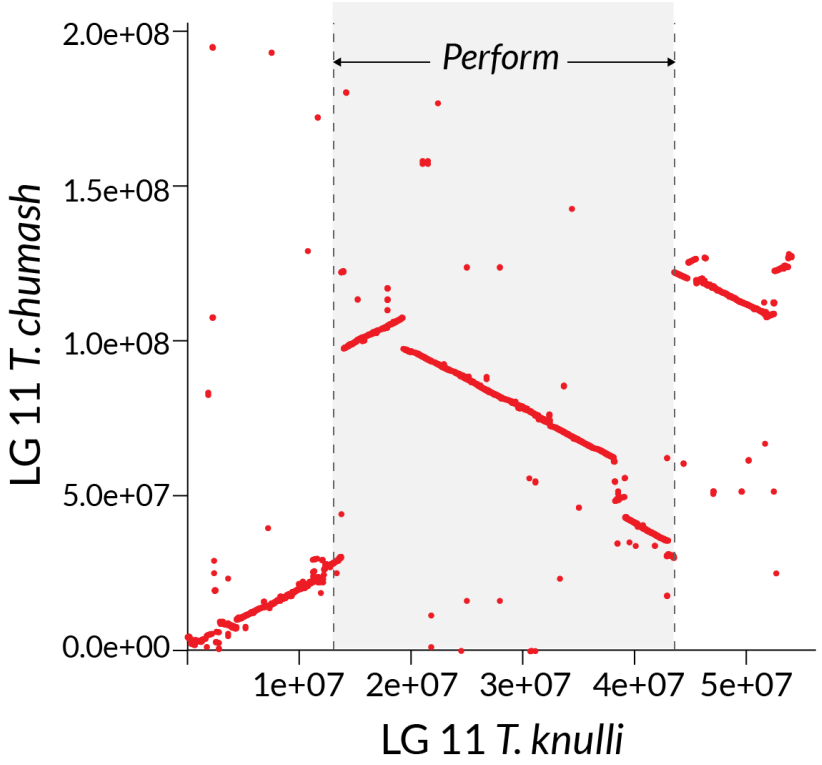


Perform is an ancient (~5-10 MYA) chromosomal inversion

T.kulli vs T. cristinae

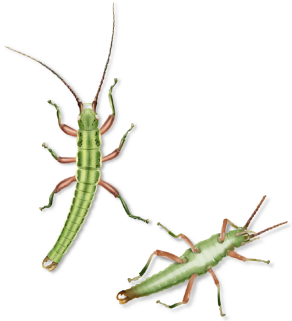


T. knulli vs T. chumash



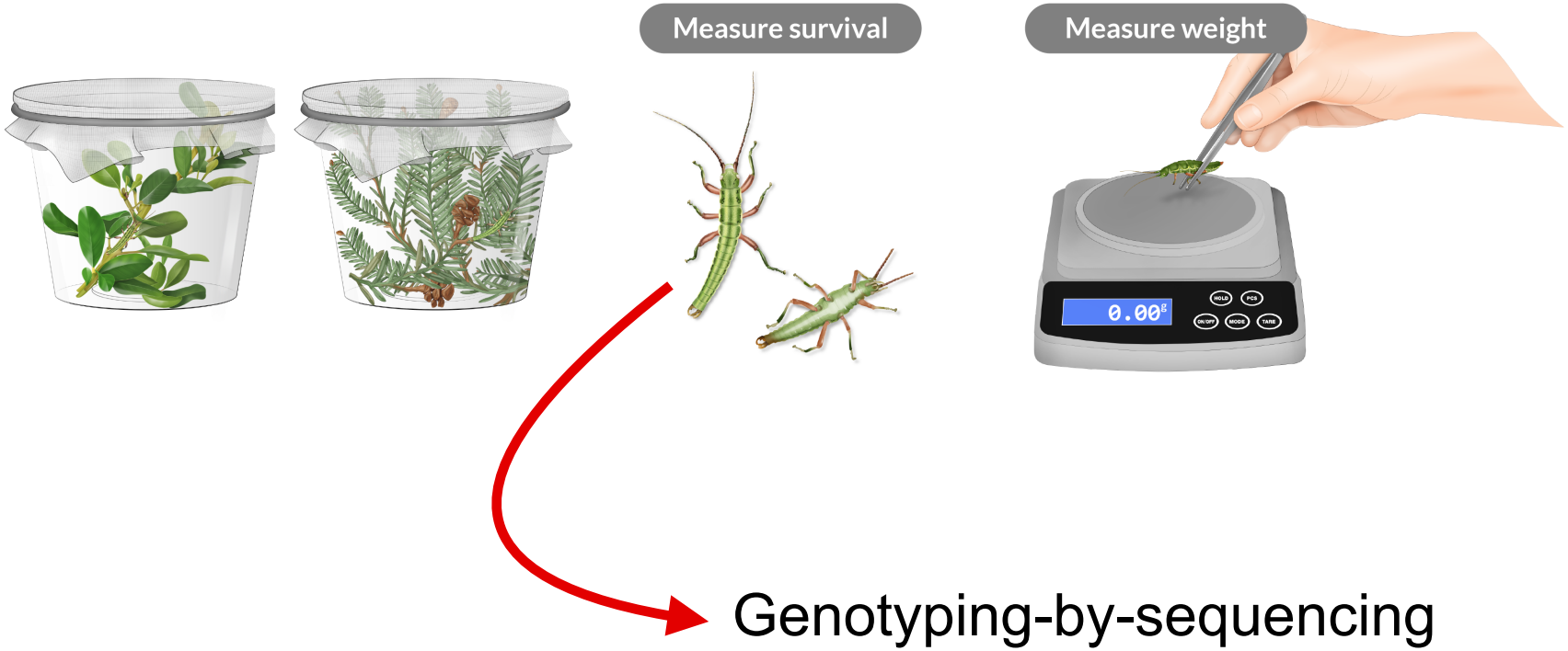
Experimental genetic analysis of fitness

Measure survival

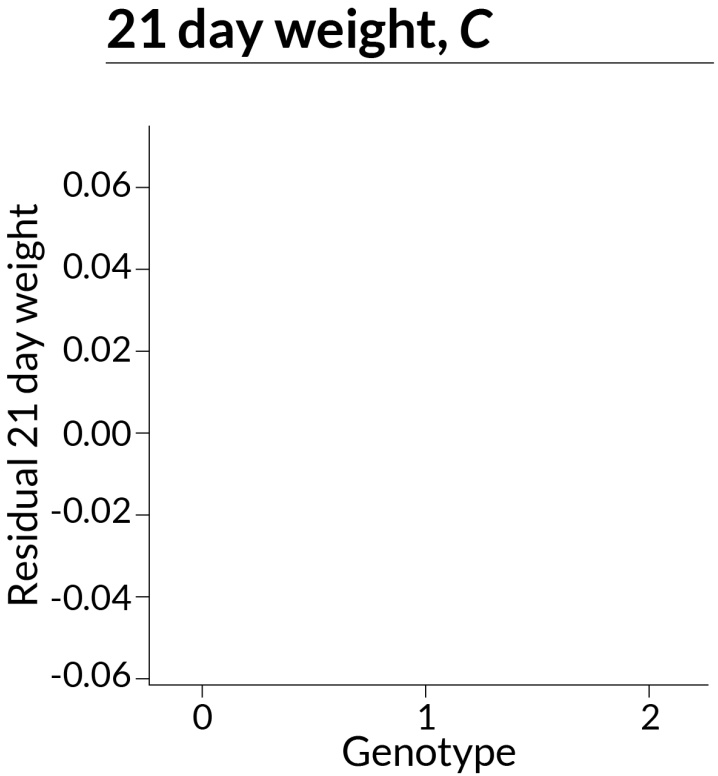


Measure weight

Experimental genetic analysis of fitness



Perform affects fitness via a life-history trade-off



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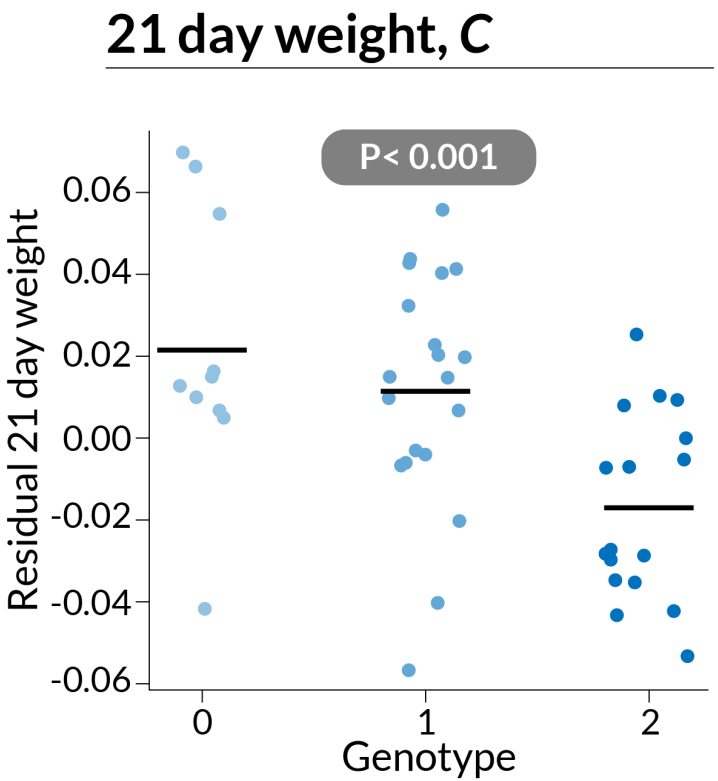

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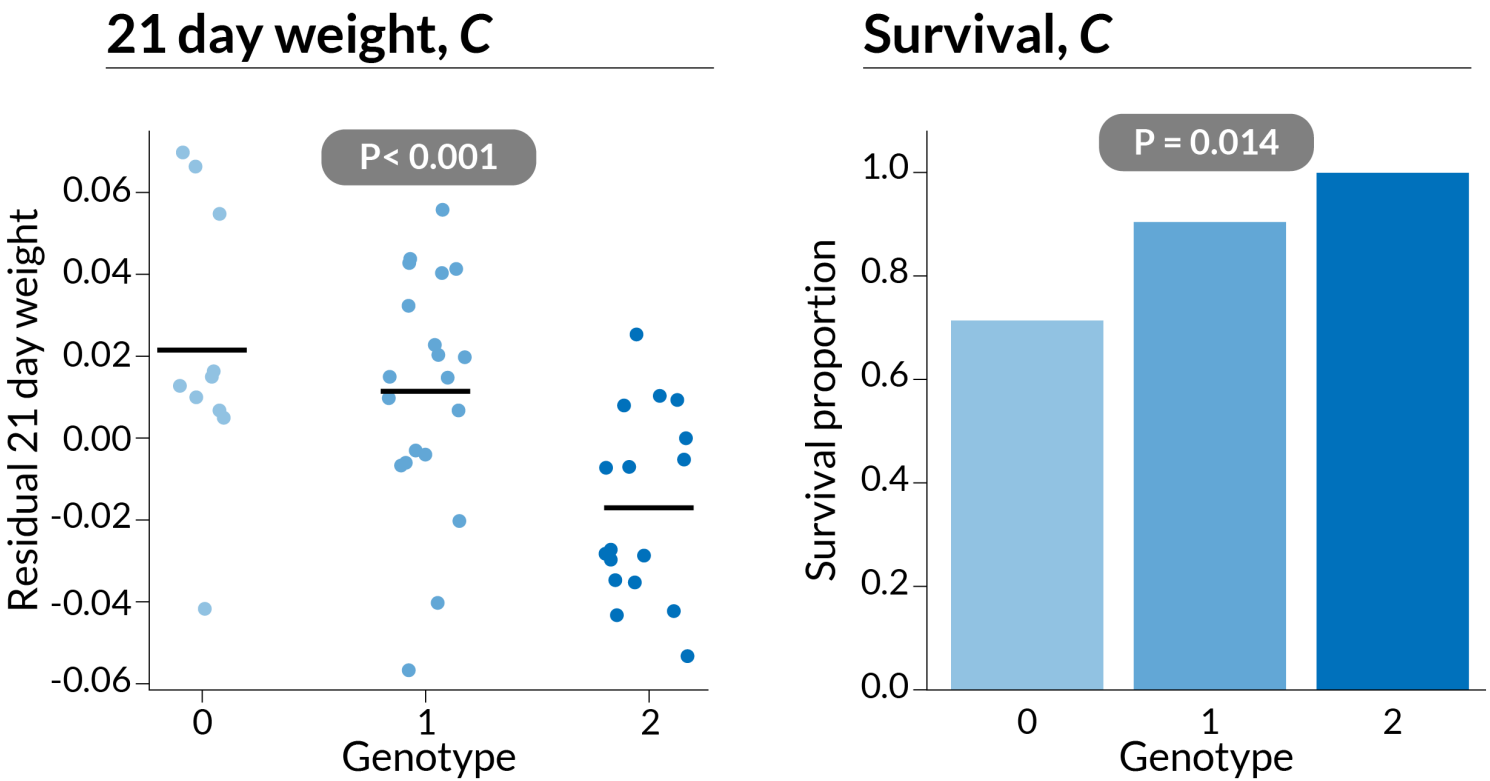

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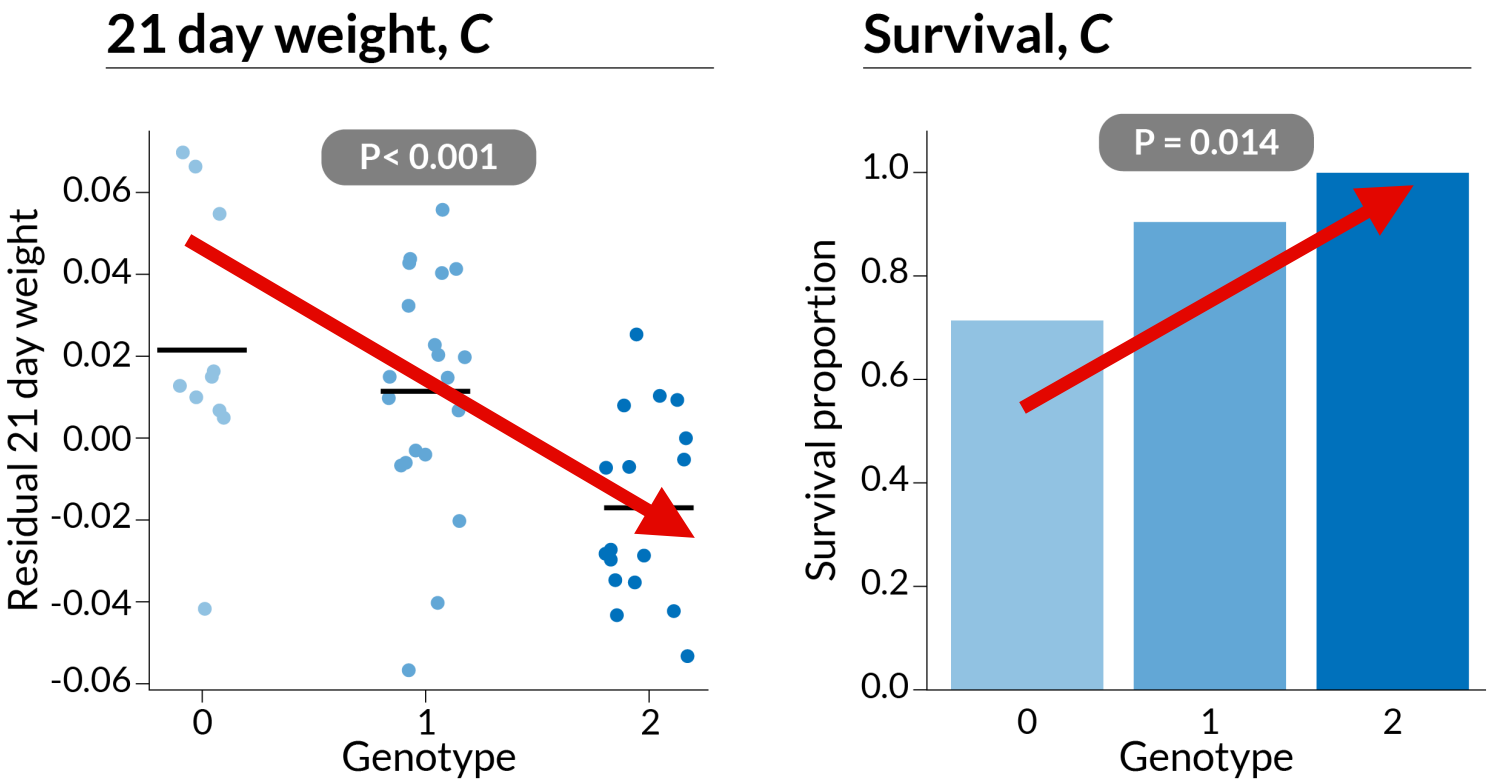

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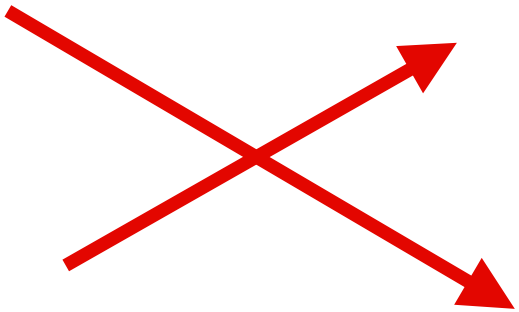


Balancing selection

Perform exhibits divergent allele-frequencies between hosts (~50% difference in 'growth allele')

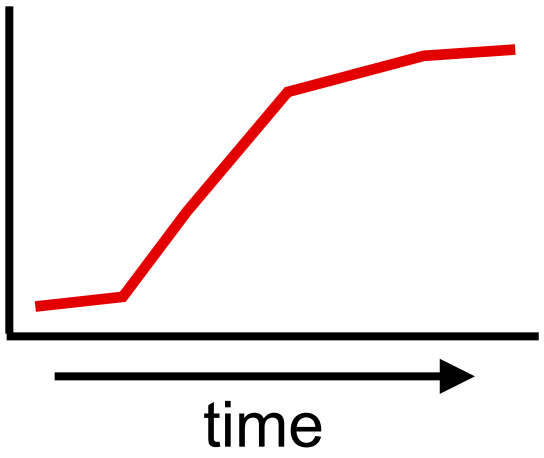
84%

Sequoia

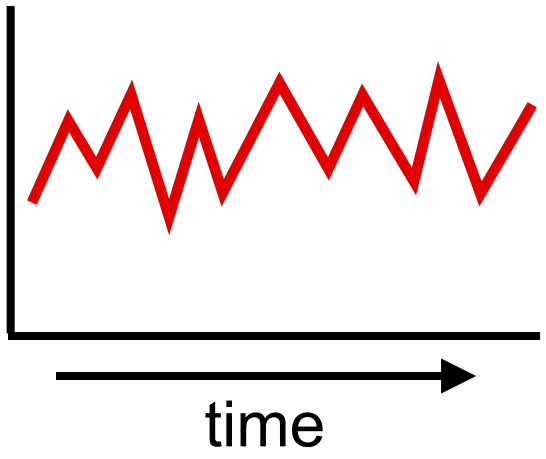
34%

Ceanothus

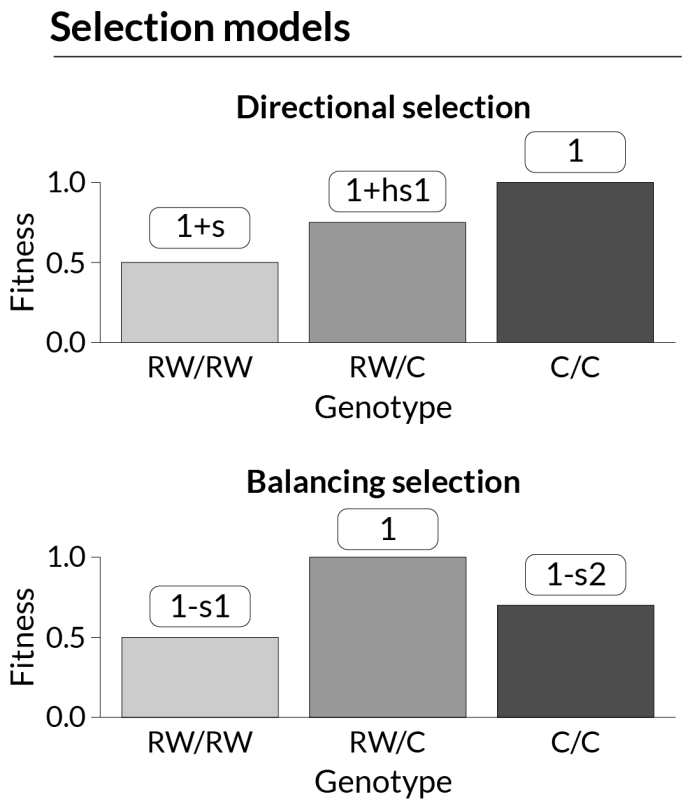
Directional evolution
(transient variation)



Fluctuating evolution
(balancing selection)

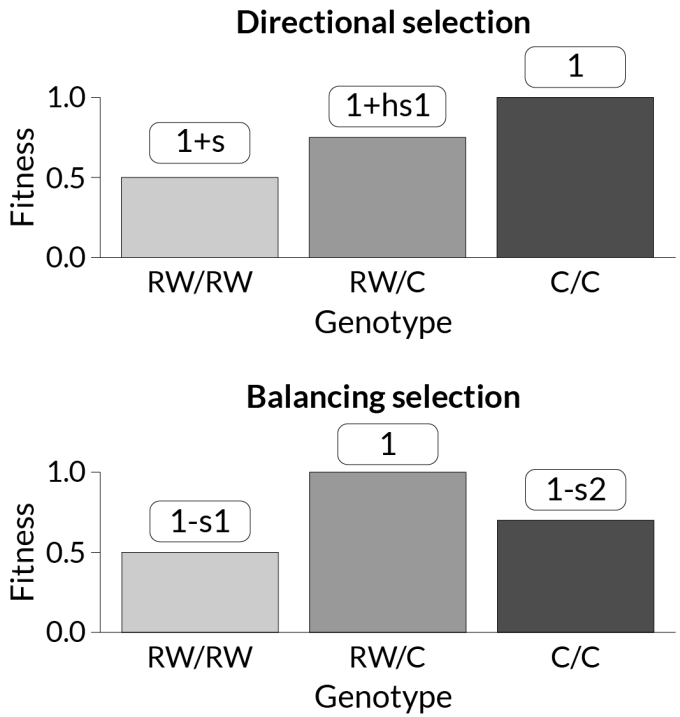


Modeled a combination of processes

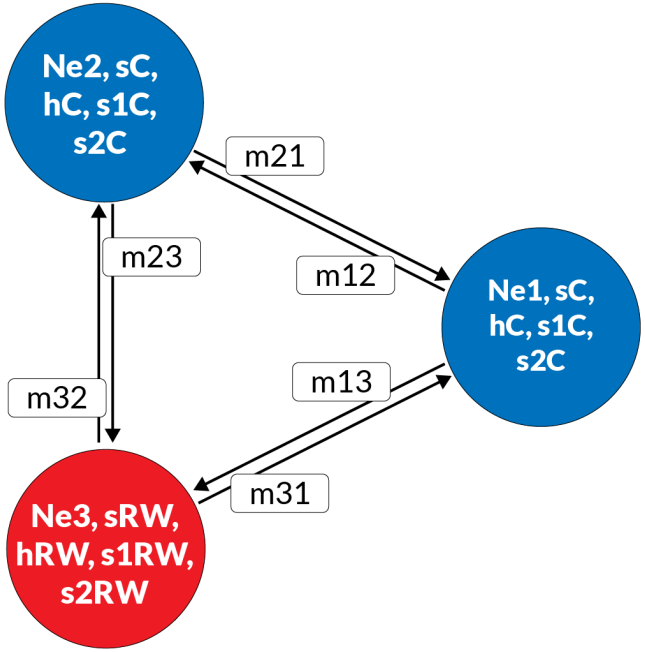


Modeled a combination of processes

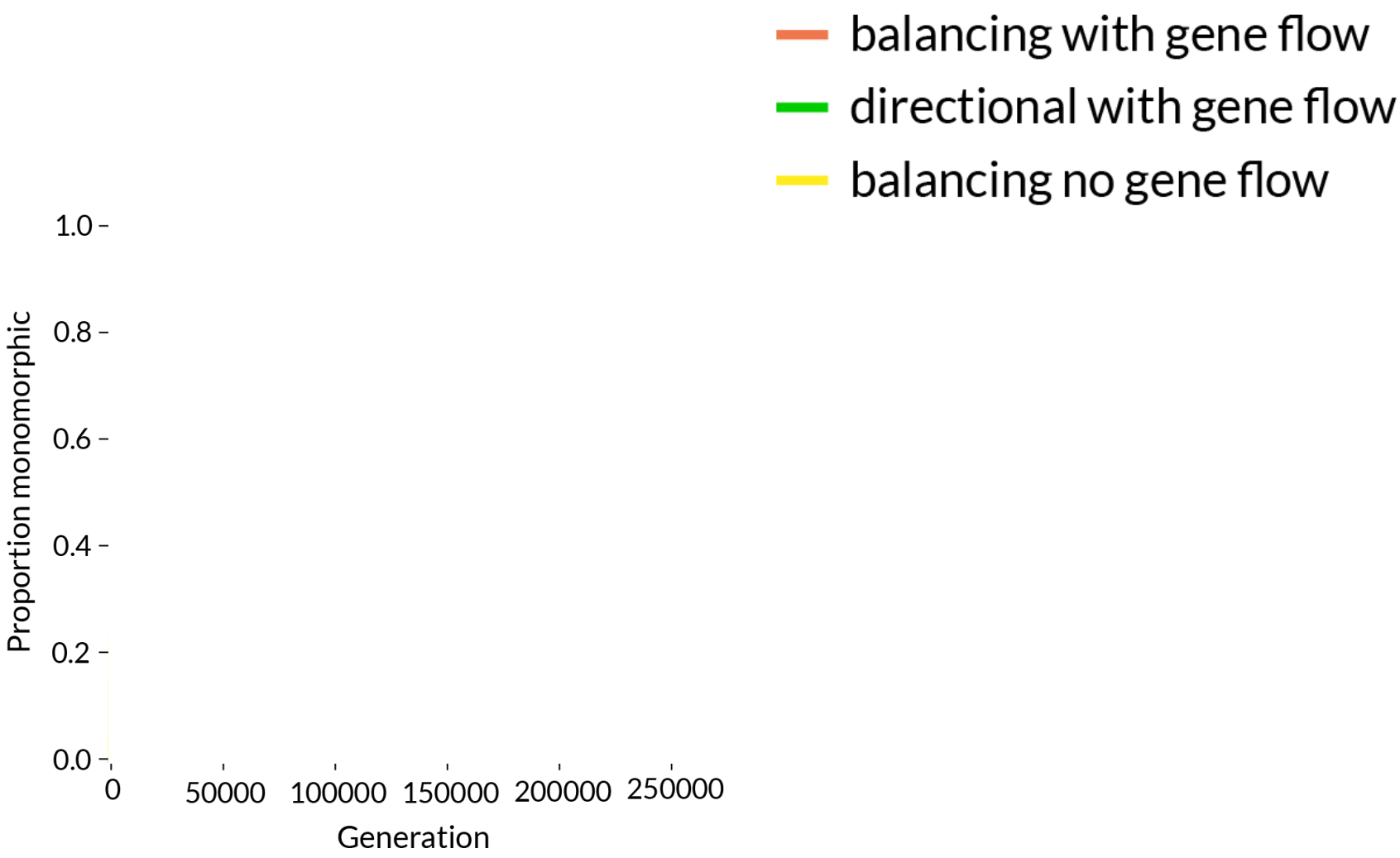
Selection models



Selection-migration model



The combination of processes best maintains variation



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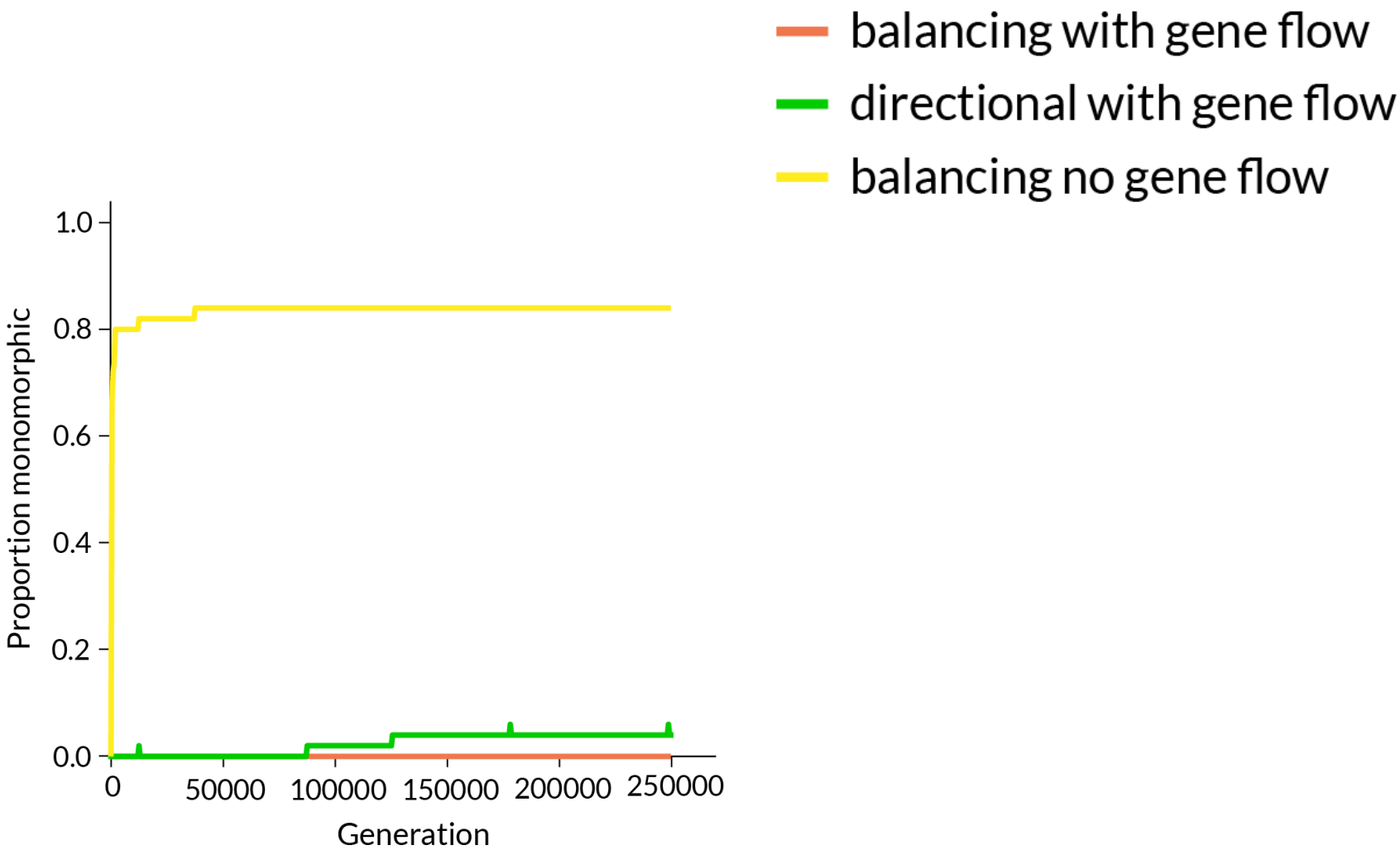

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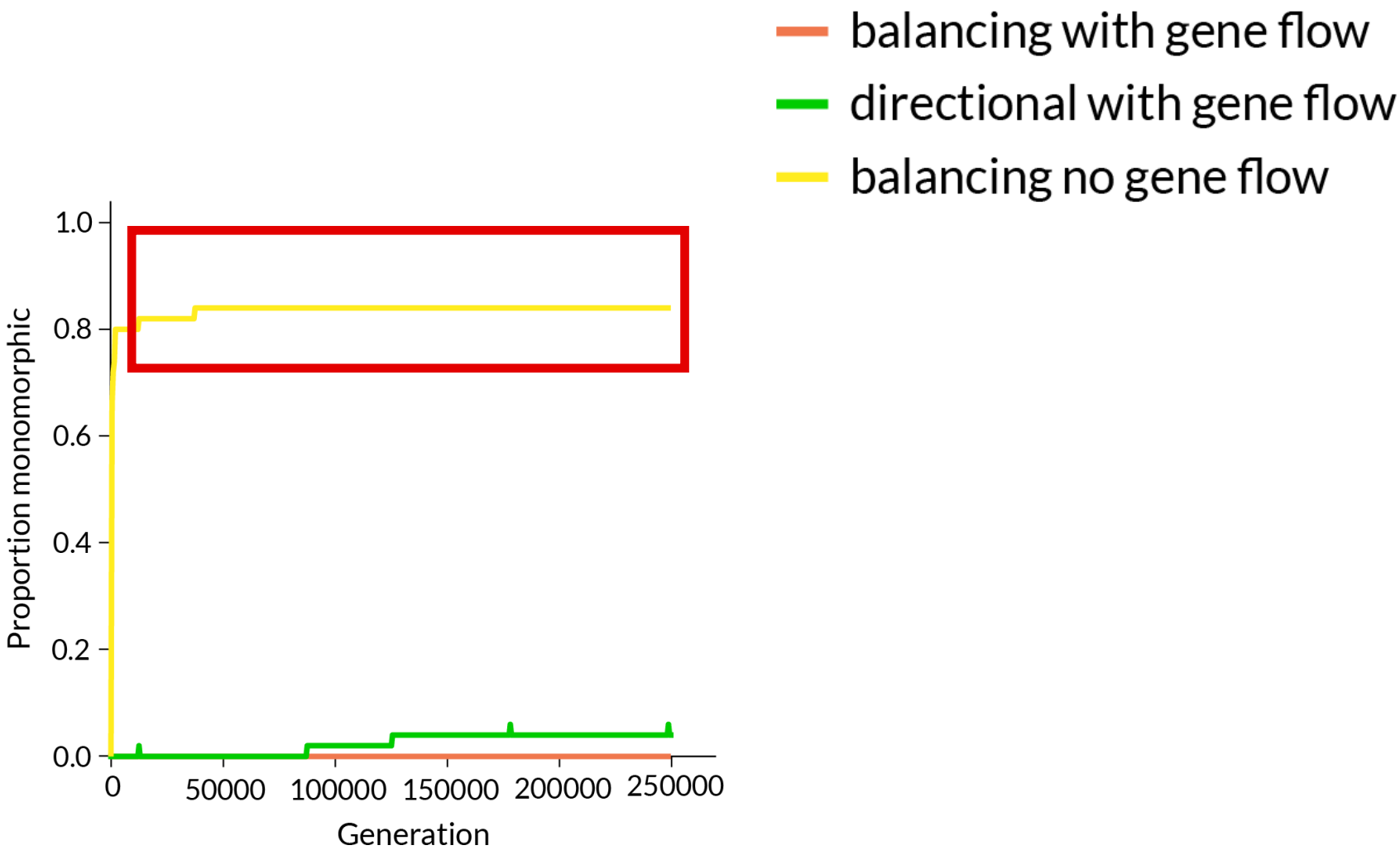

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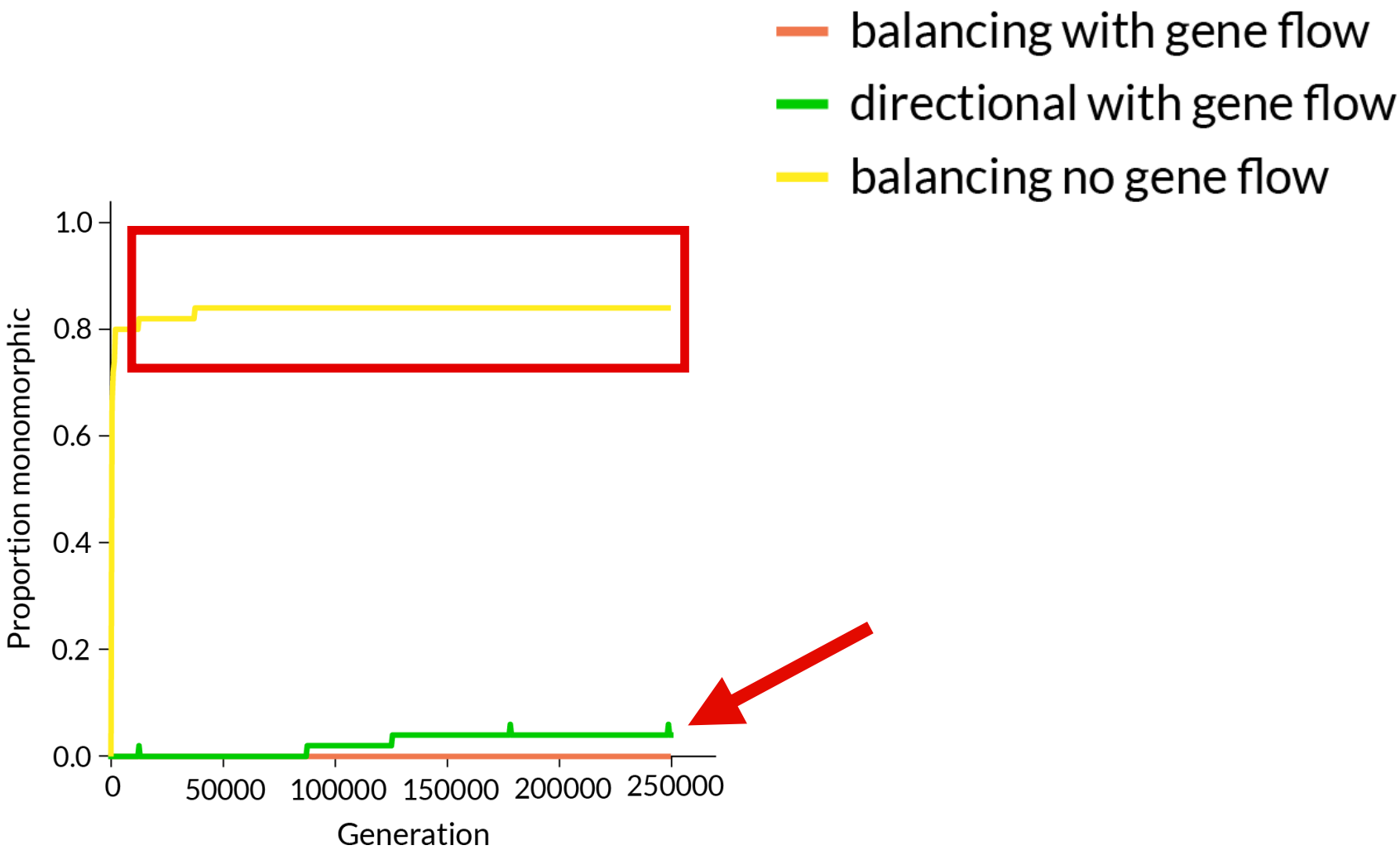

Complexity of evolutionary process provides resilience against loss of genetic variation

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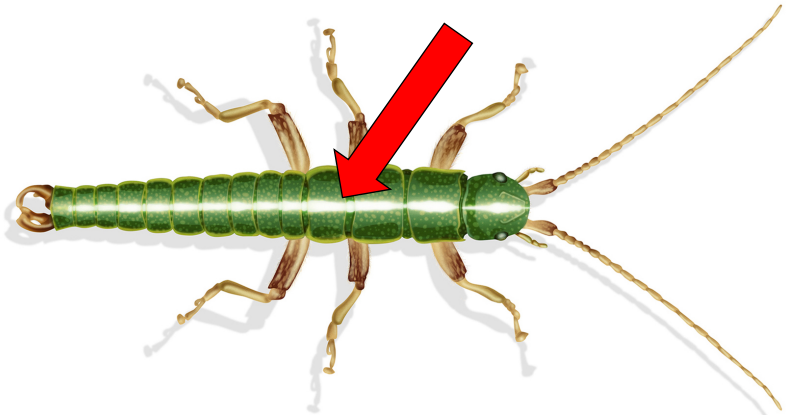
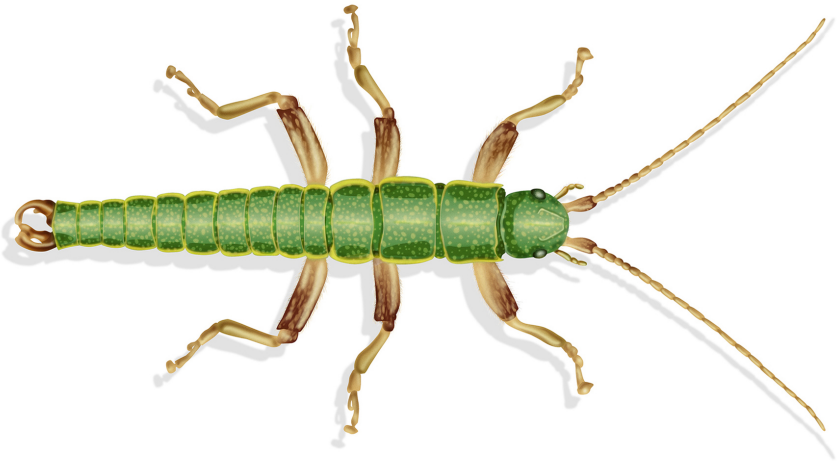
A *ADENOSTOMA* ECOTYPE



B *CEANOTHUS* ECOTYPE




M. Muschick photo


M. Muschick photo

Divergent morph frequencies between hosts

~80%

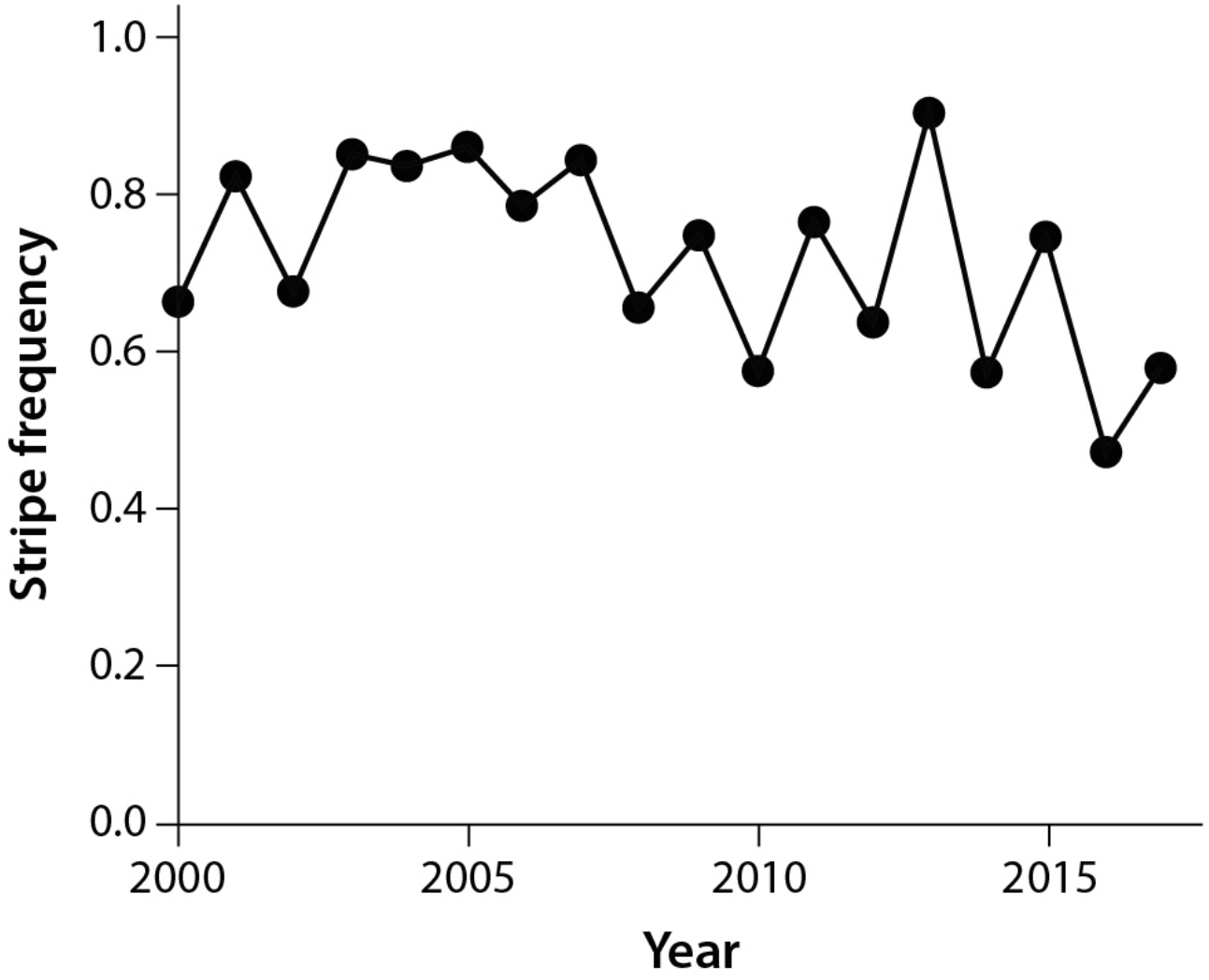
Adenostoma

~20%

Ceanothus

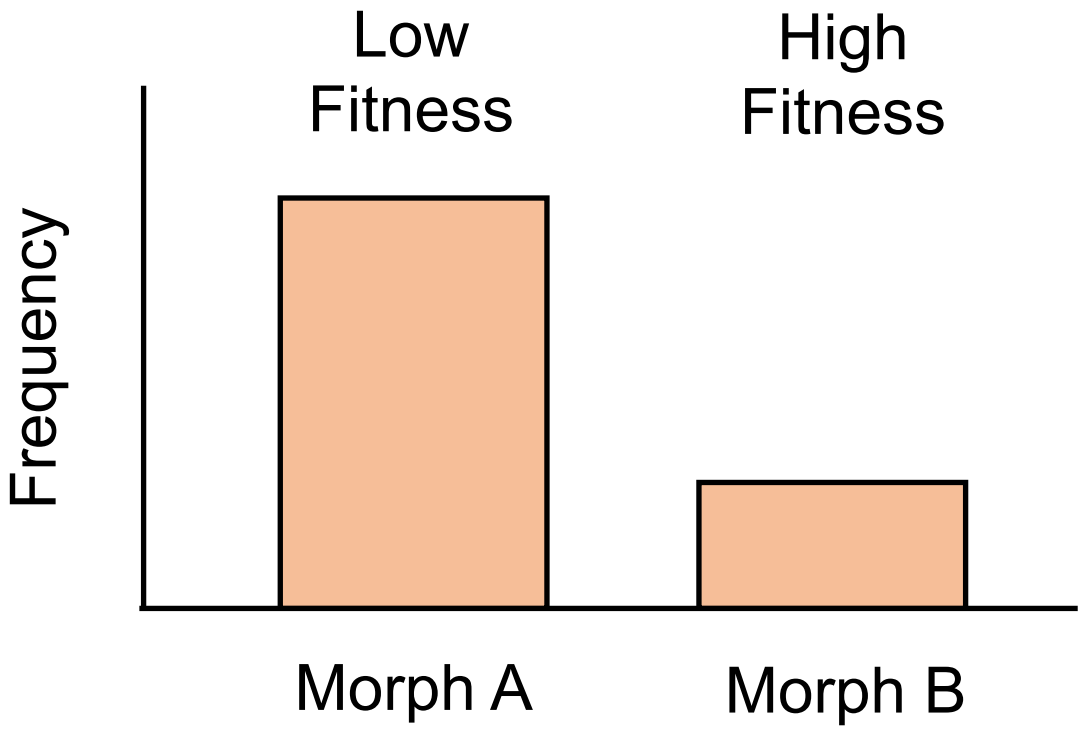
Nosil *et al.* 2018 *Science*

Predictable fluctuations in color-pattern morph frequencies



Nosil *et al.* 2018 *Science*

NFDS: fitness depends on frequency



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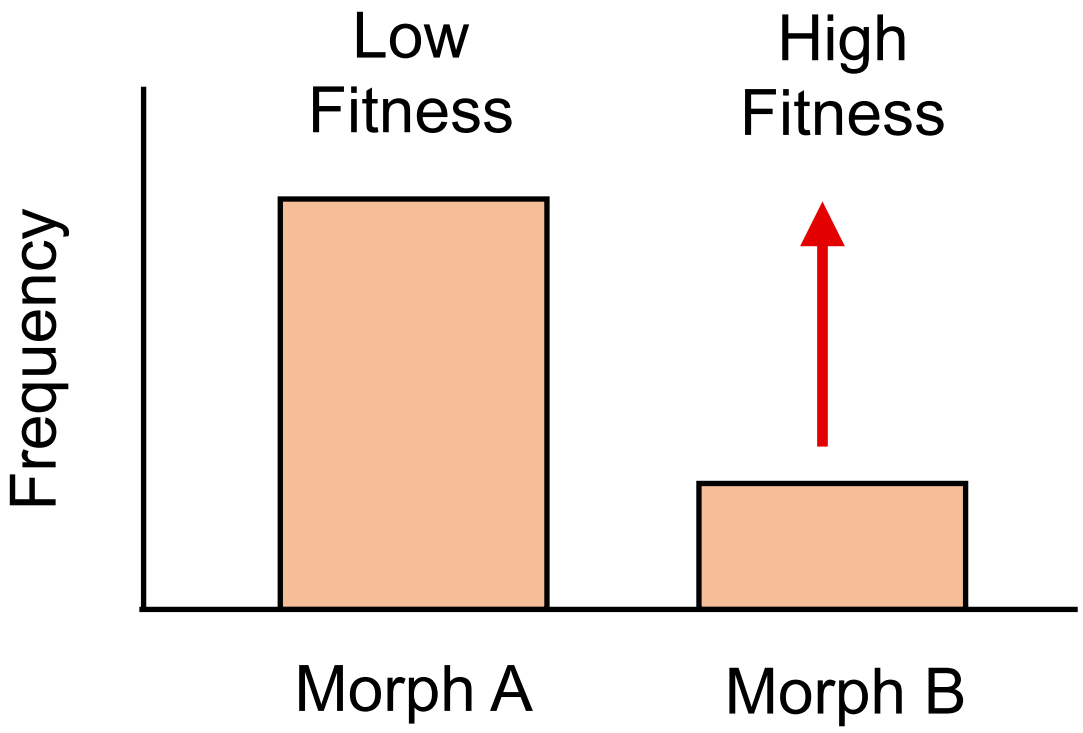

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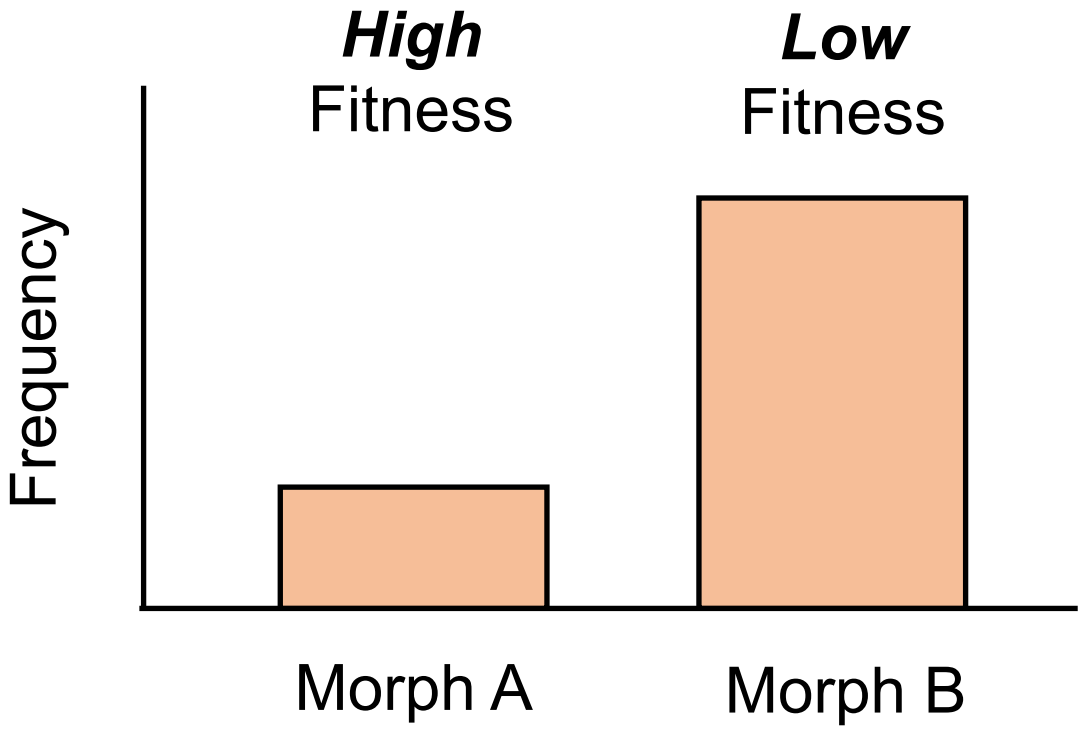
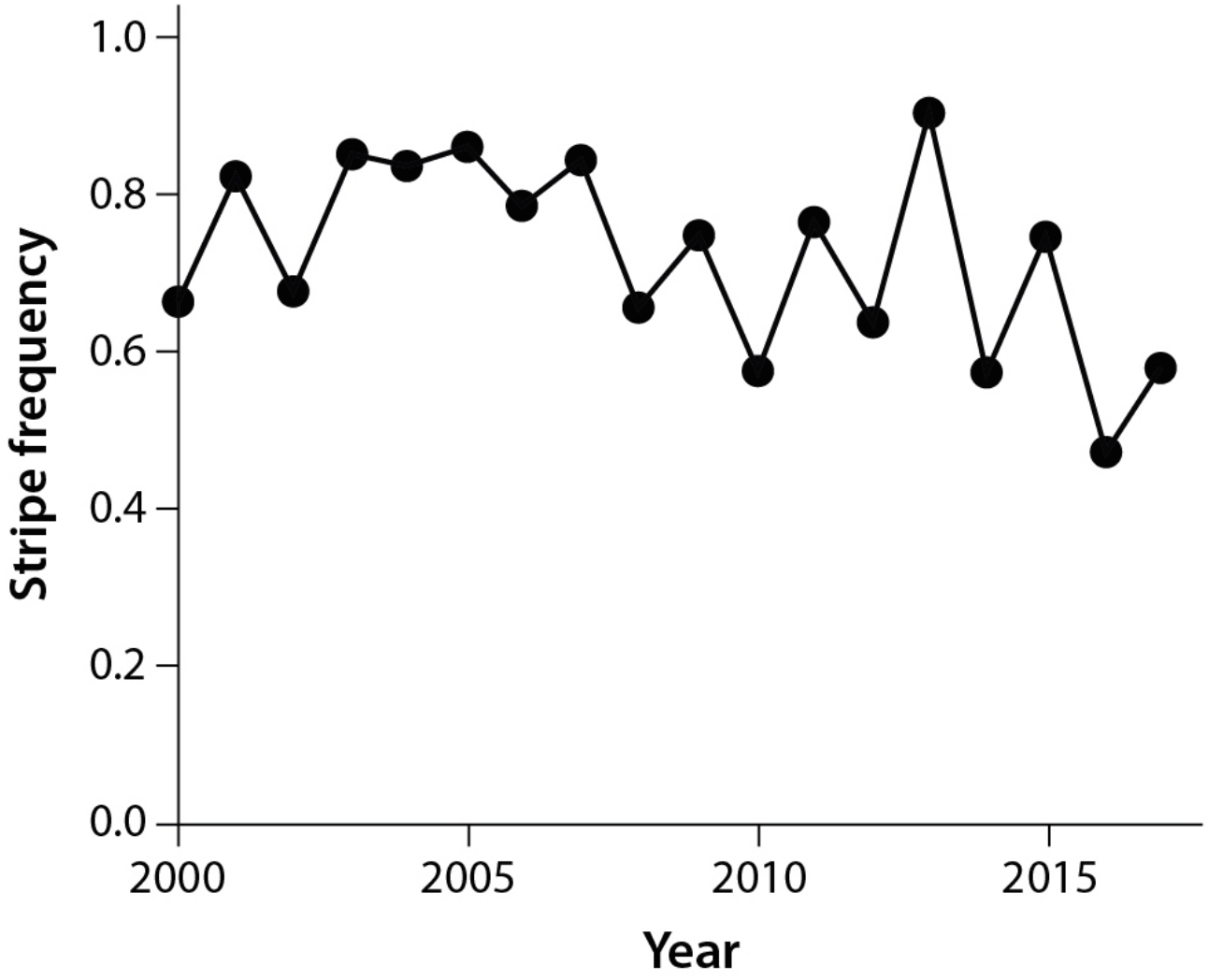


Predictable fluctuations in color-pattern morph frequencies



Nosil *et al.* 2018 *Science*

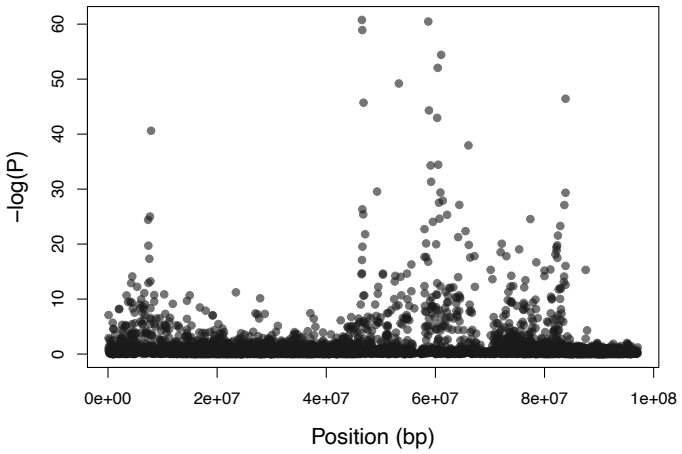
1) Genetic scan

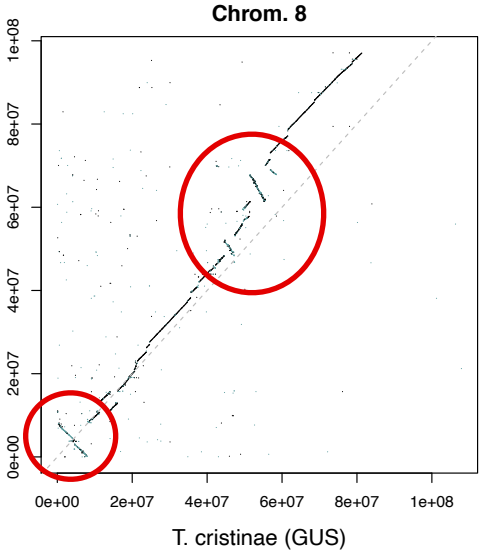
2) Compare independent genome assemblies

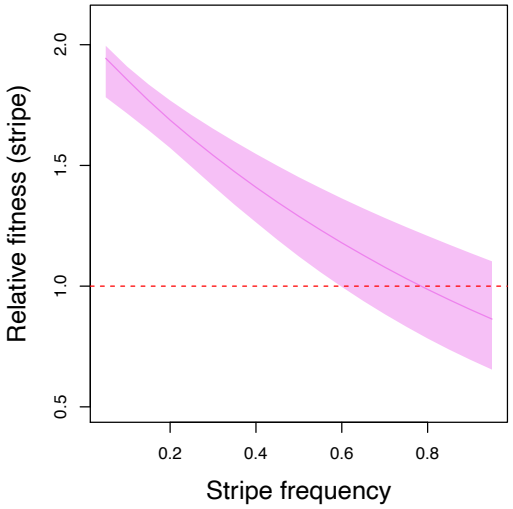
3) Experimental analysis of fitness

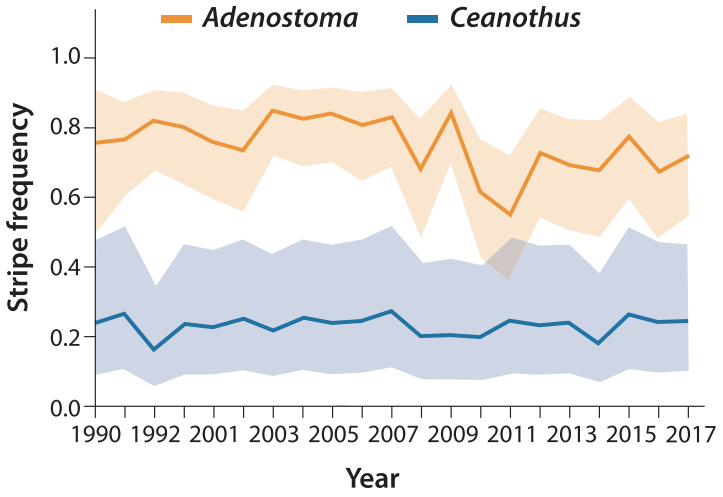
4) Modeling of allele-frequency variation

Once again, combined processes best maintain variation







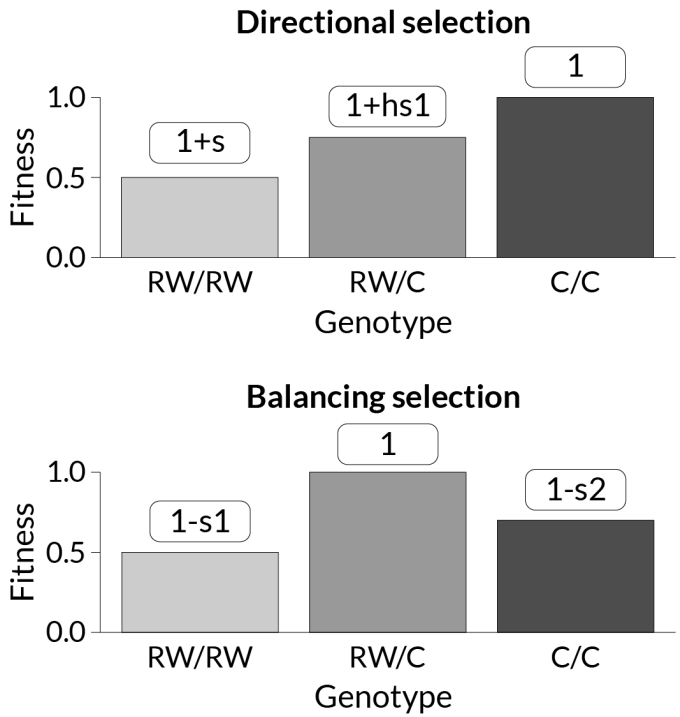


Many forms of selection and random drift deplete genetic variation

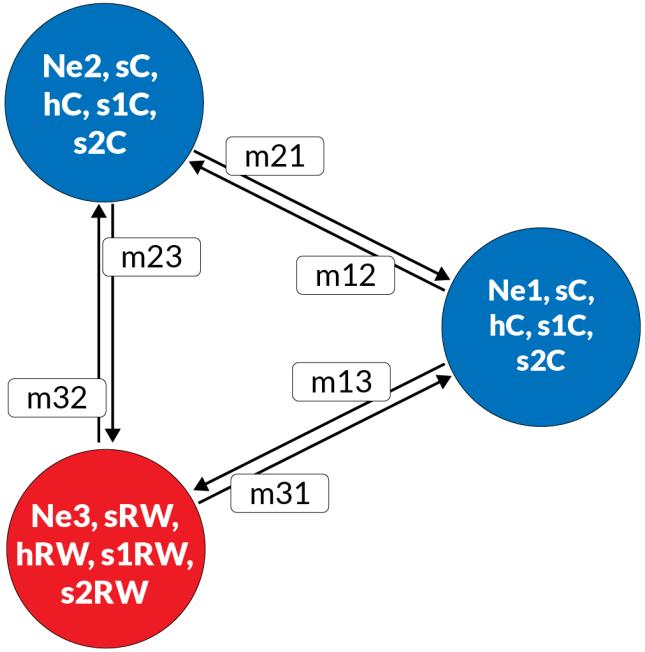
So, how is variation maintained over long-time periods?

Modeled a combination of processes

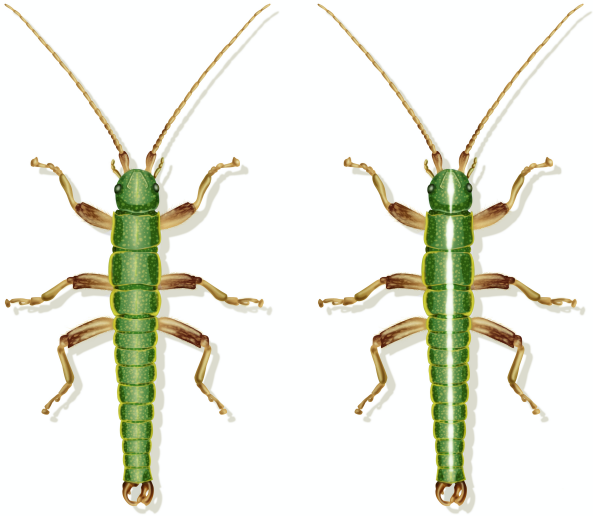
Selection models



Selection-migration model



Complexity of evolutionary process provides resilience against the loss of genetic variation

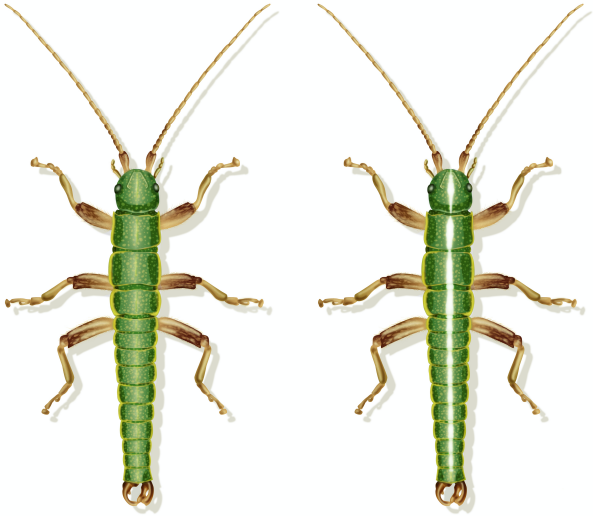


Complexity of evolutionary process provides resilience against the loss of genetic variation

Directional selection

Life-history trade-off

Migration



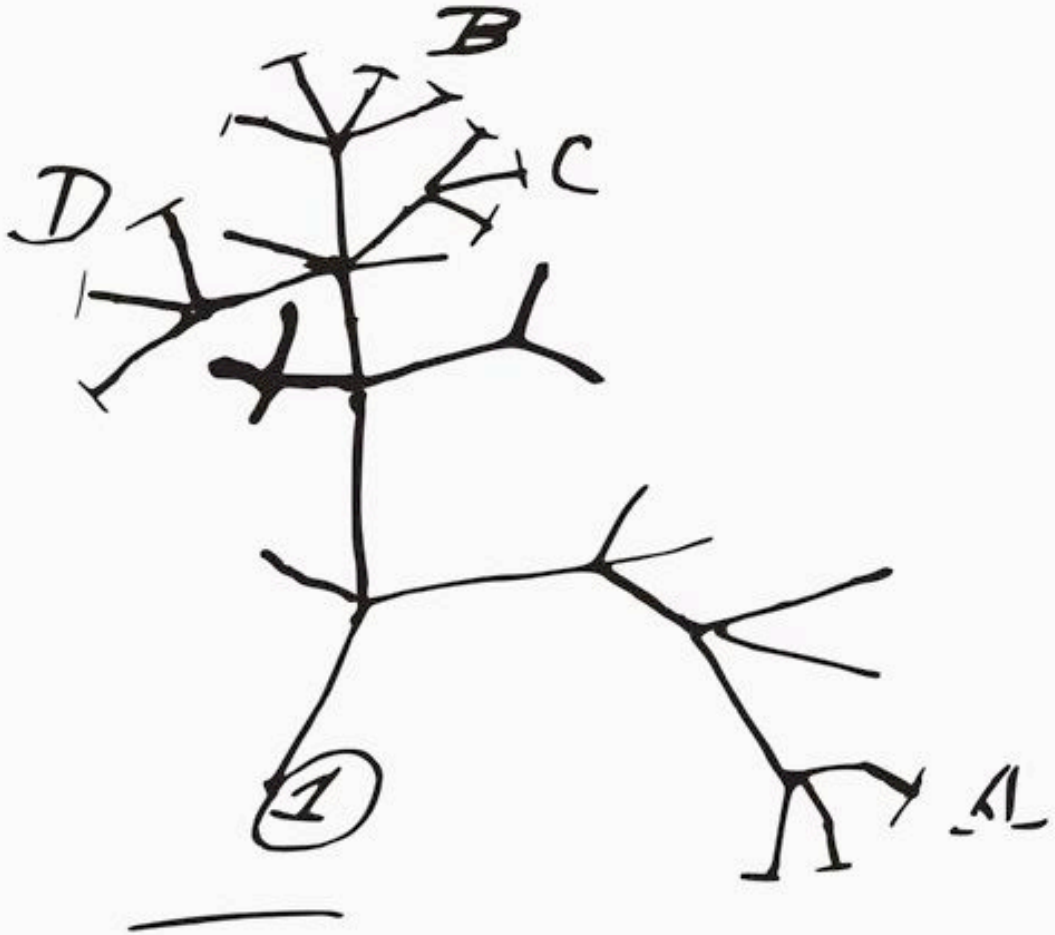
Directional selection

NFDS

Migration

What about preferences?

I think



Divergent host-plant preferences can cause reproductive isolation, and thus affect speciation

Sequoia

Ceanothus

Divergent host-plant preferences can cause reproductive isolation, and thus affect speciation

Sequoia

Ceanothus

1) *Timema* stick insect system

2) Maintaining genomic variation for diet

3) Evolution of host preference

PHILOSOPHICAL TRANSACTIONS B

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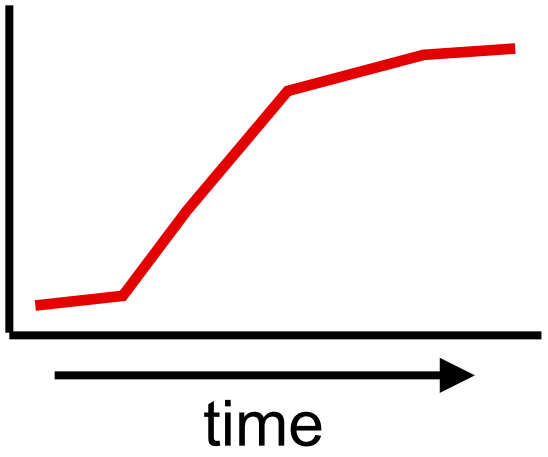
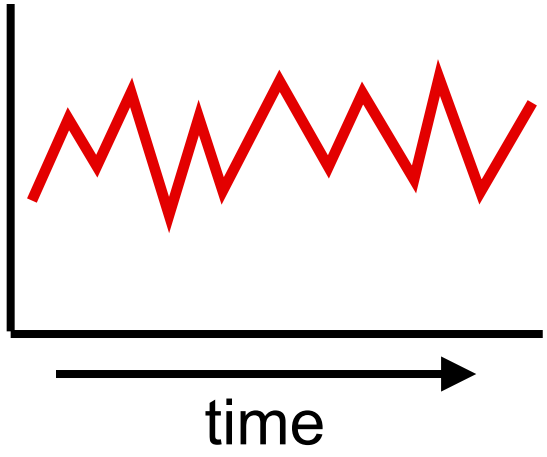
Adaptive zones shape the magnitude of premating reproductive isolation in *Timema* stick insects

Moritz Muschick[1,2,3,†], Víctor Soria-Carrasco[1,4,†], Jeffrey L. Feder[5], Zach Gompert[6] and Patrik Nosil[1,7]

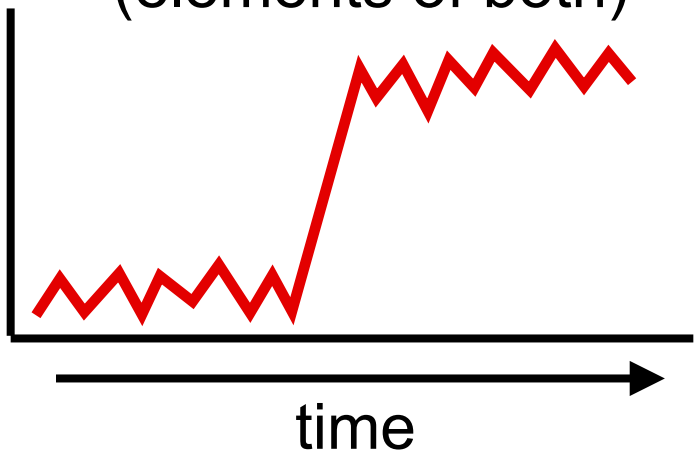
Directional evolution
(transient variation)



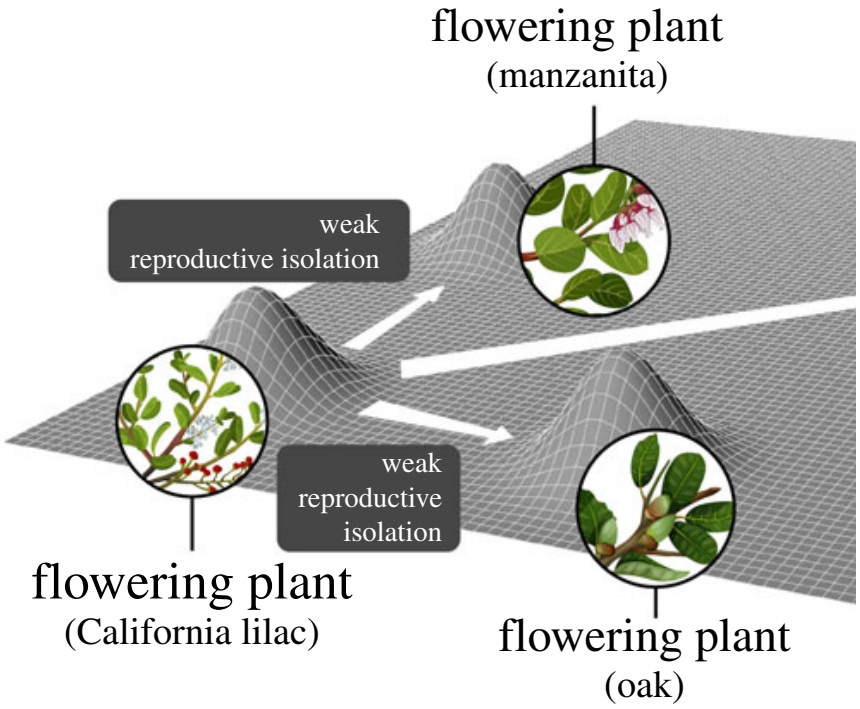
Fluctuating evolution
(balancing selection)



Simpson's adaptive zones
(elements of both)

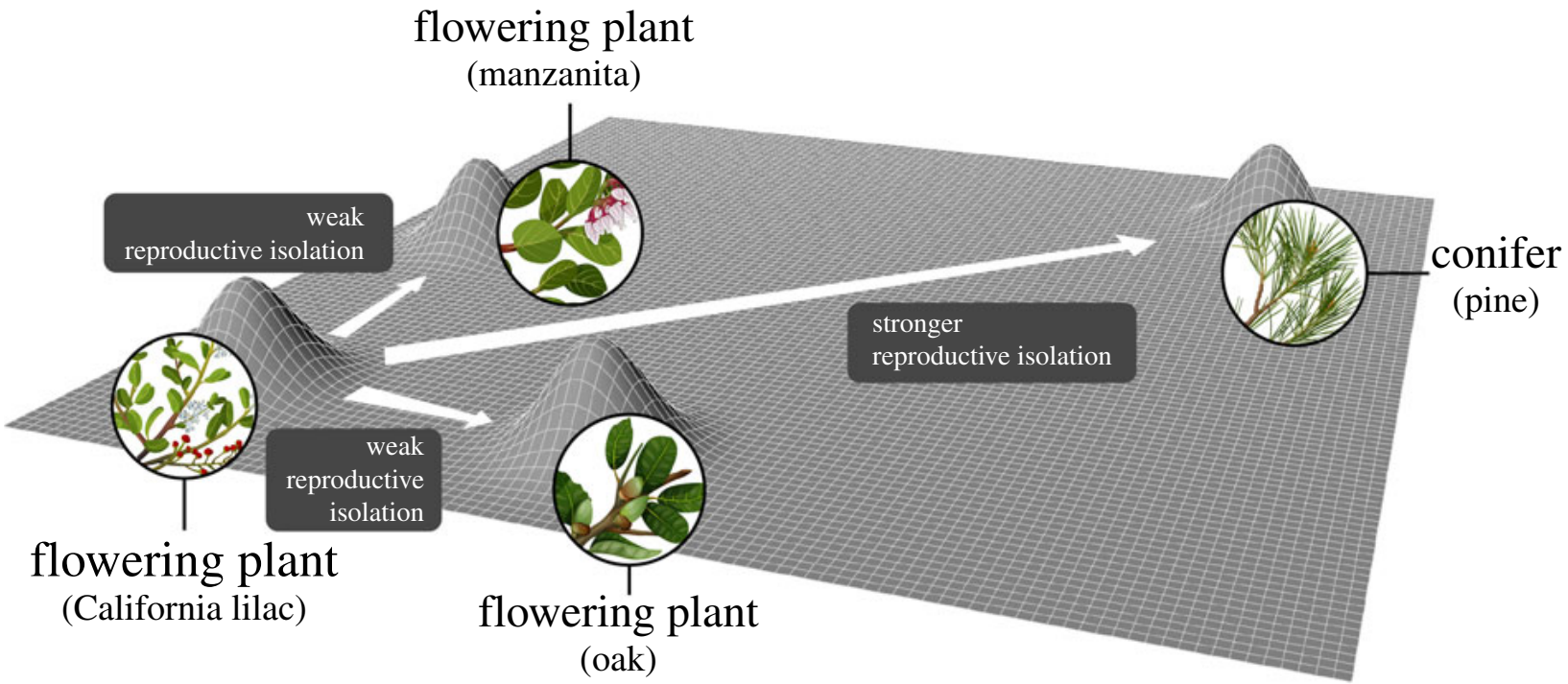


Simpson's adaptive zones applied to preference evolution



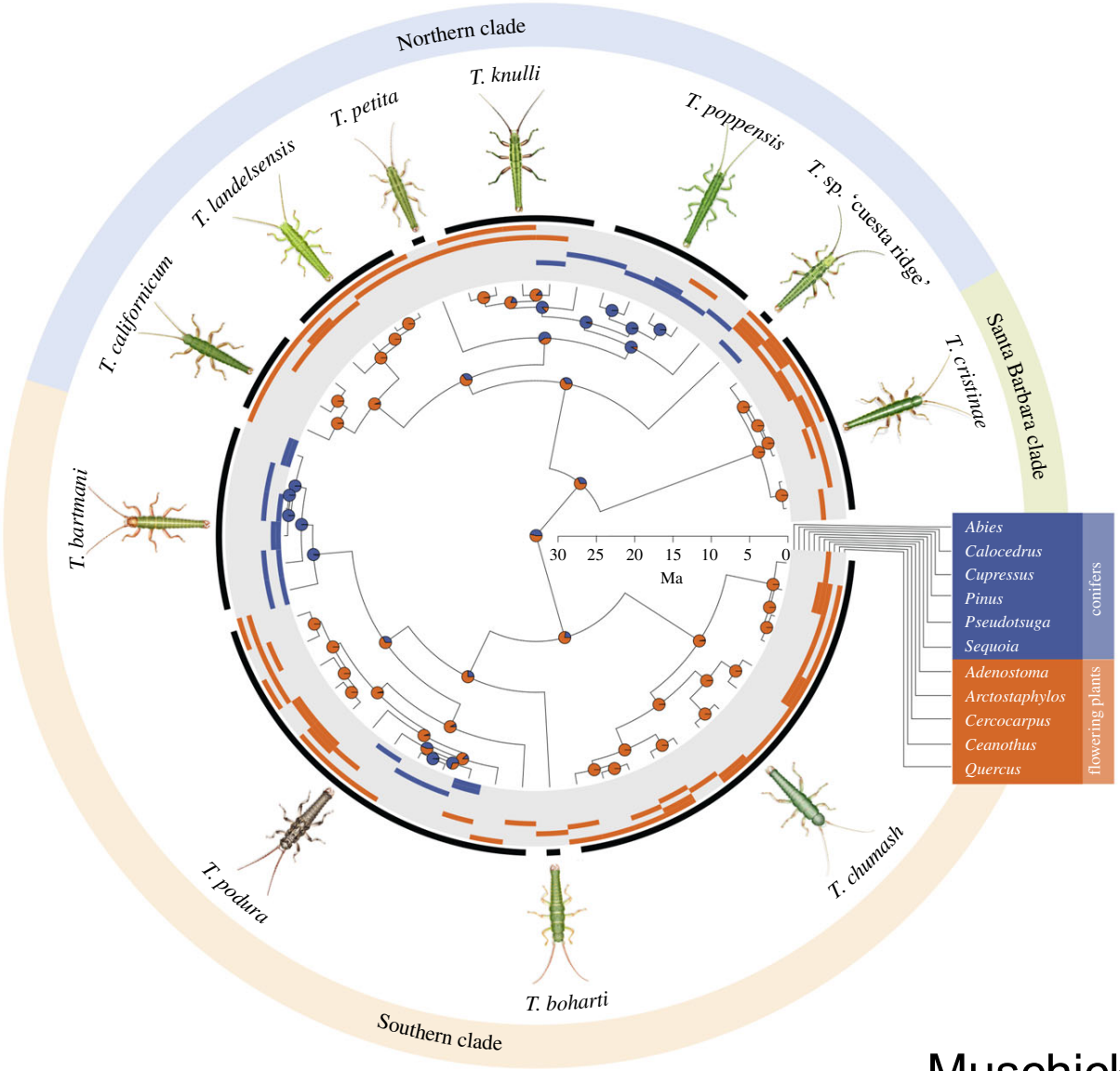
Muschick *et al.* 2020 *Phil Trans B*

Simpson's adaptive zones applied to preference evolution



Muschick *et al.* 2020 *Phil Trans B*

Shifts between plant divisions are rare (~1 every 10 MY)



Muschick *et al.* 2020 *Phil Trans B*

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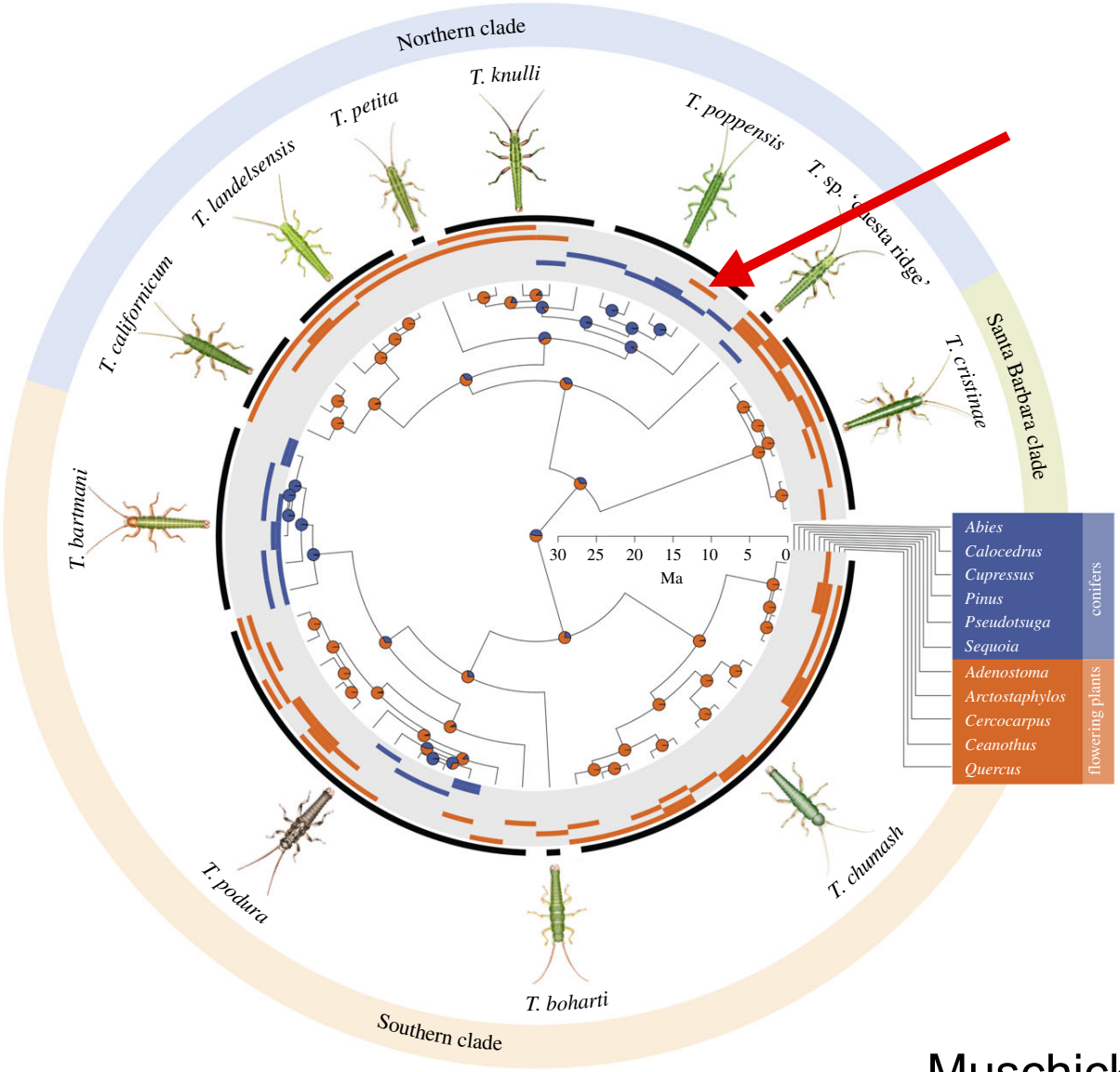

Muschick *et al.* 2020 *Phil Trans B*

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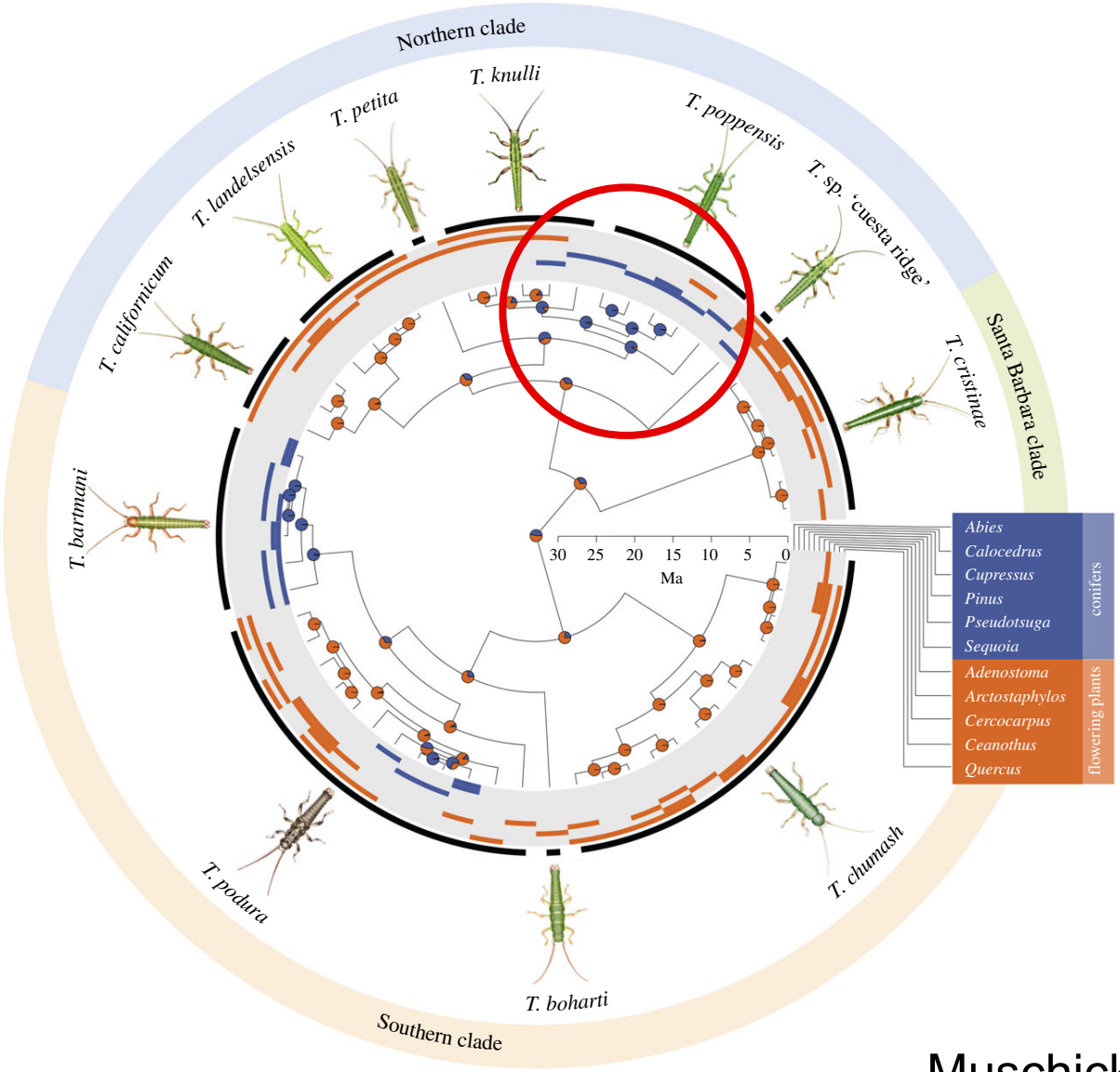
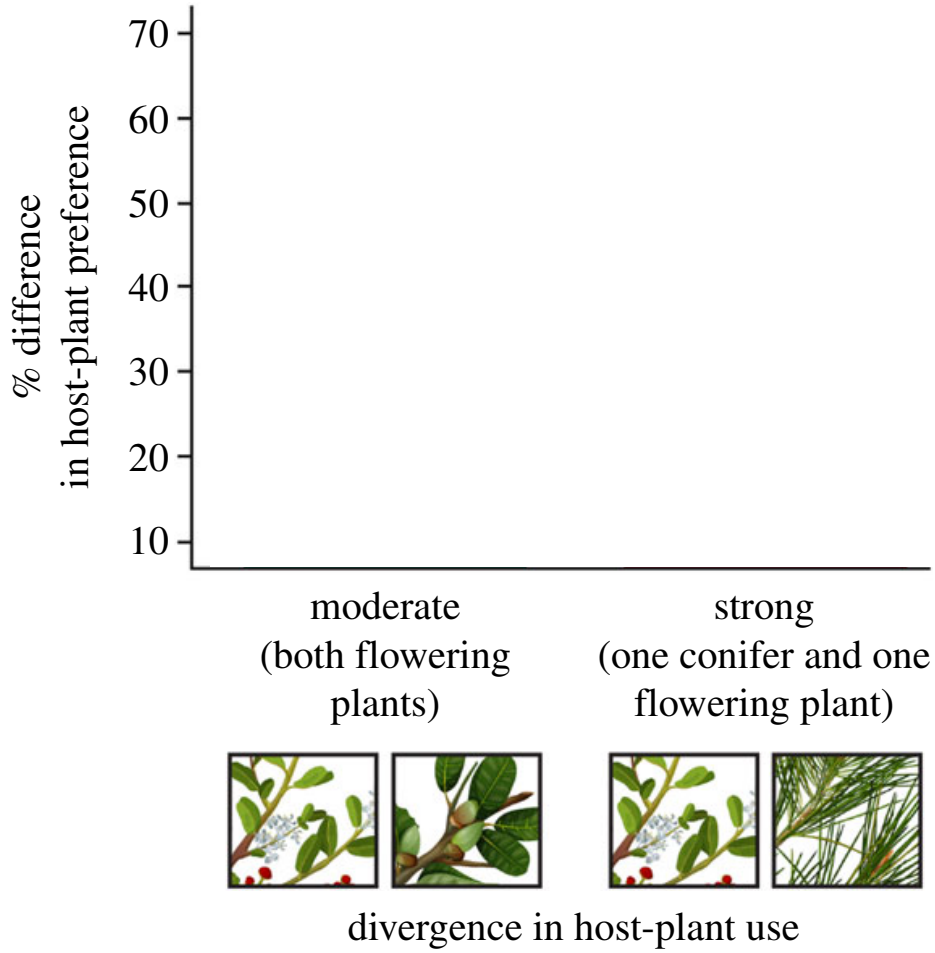


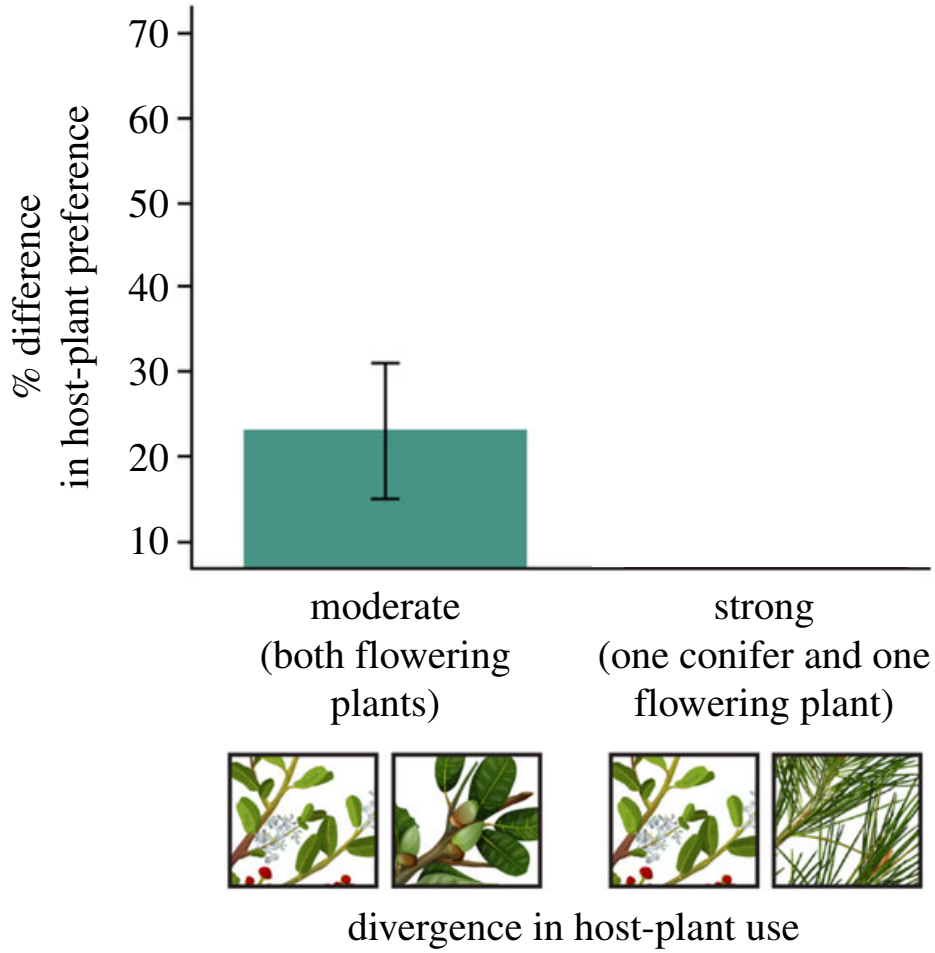
Muschick *et al.* 2020 *Phil Trans B*

Shifts between plant divisions generate preference evolution



Muschick *et al.* 2020 *Phil Trans B*

Shifts between plant divisions generate preference evolution



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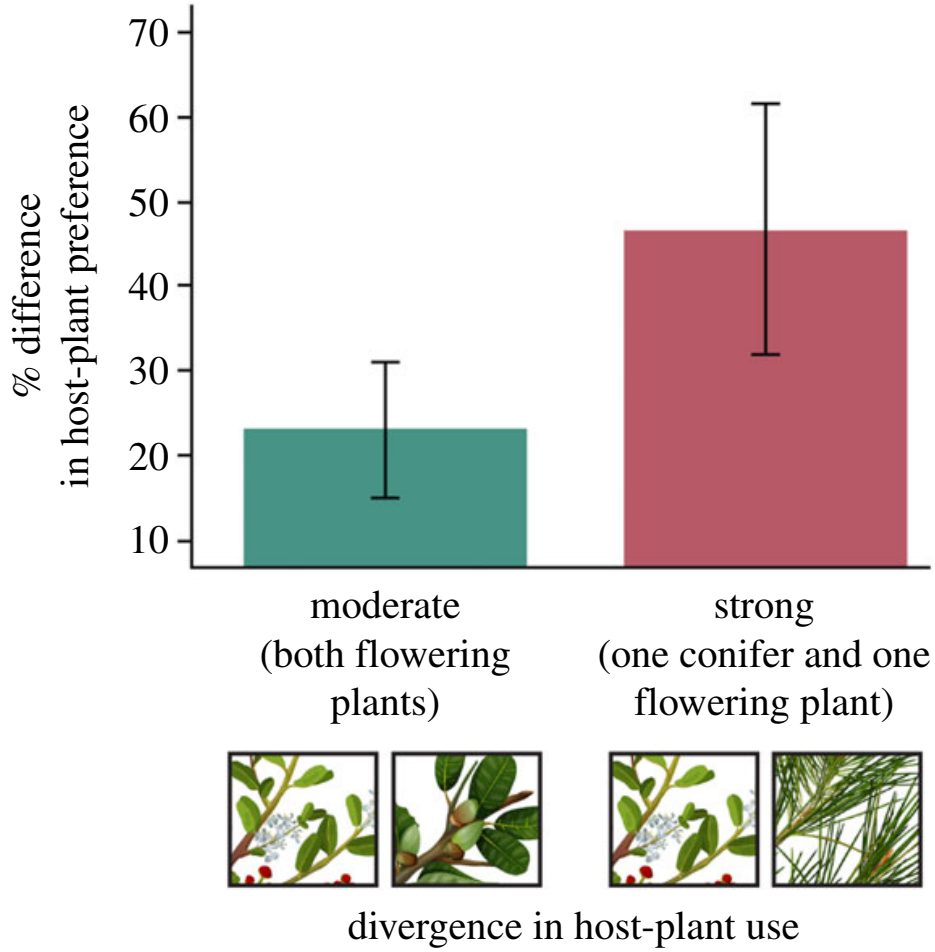

Muschick *et al.* 2020 *Phil Trans B*

Directional evolution
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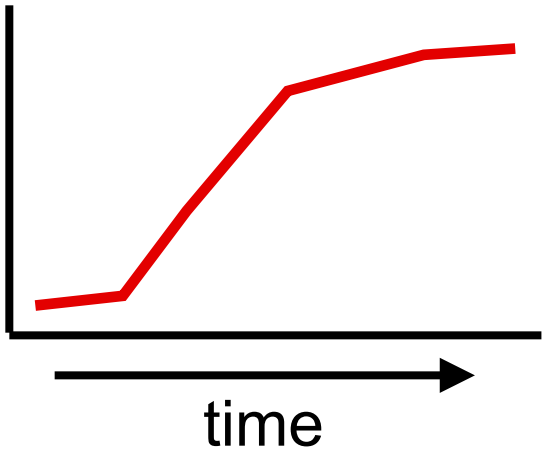

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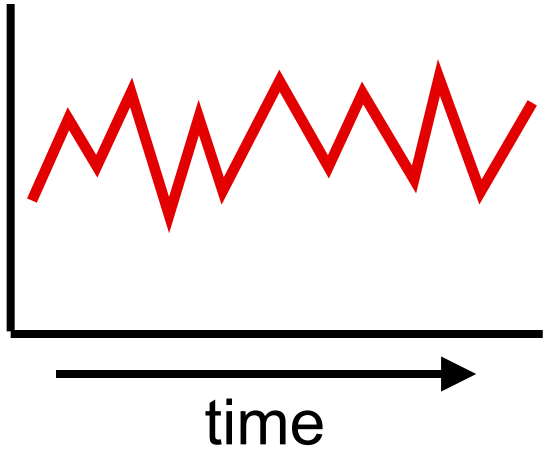

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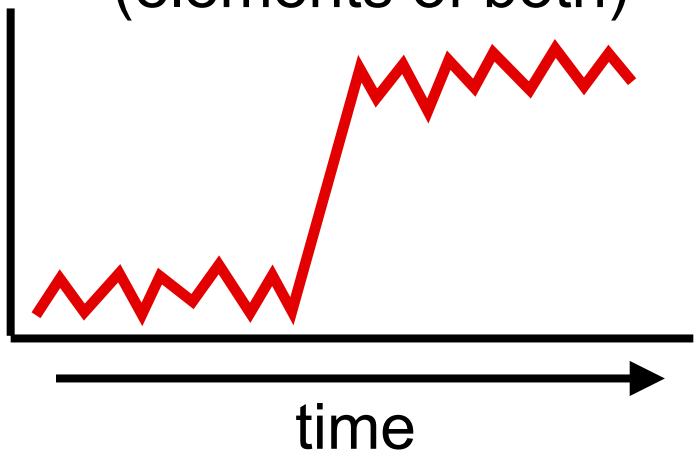

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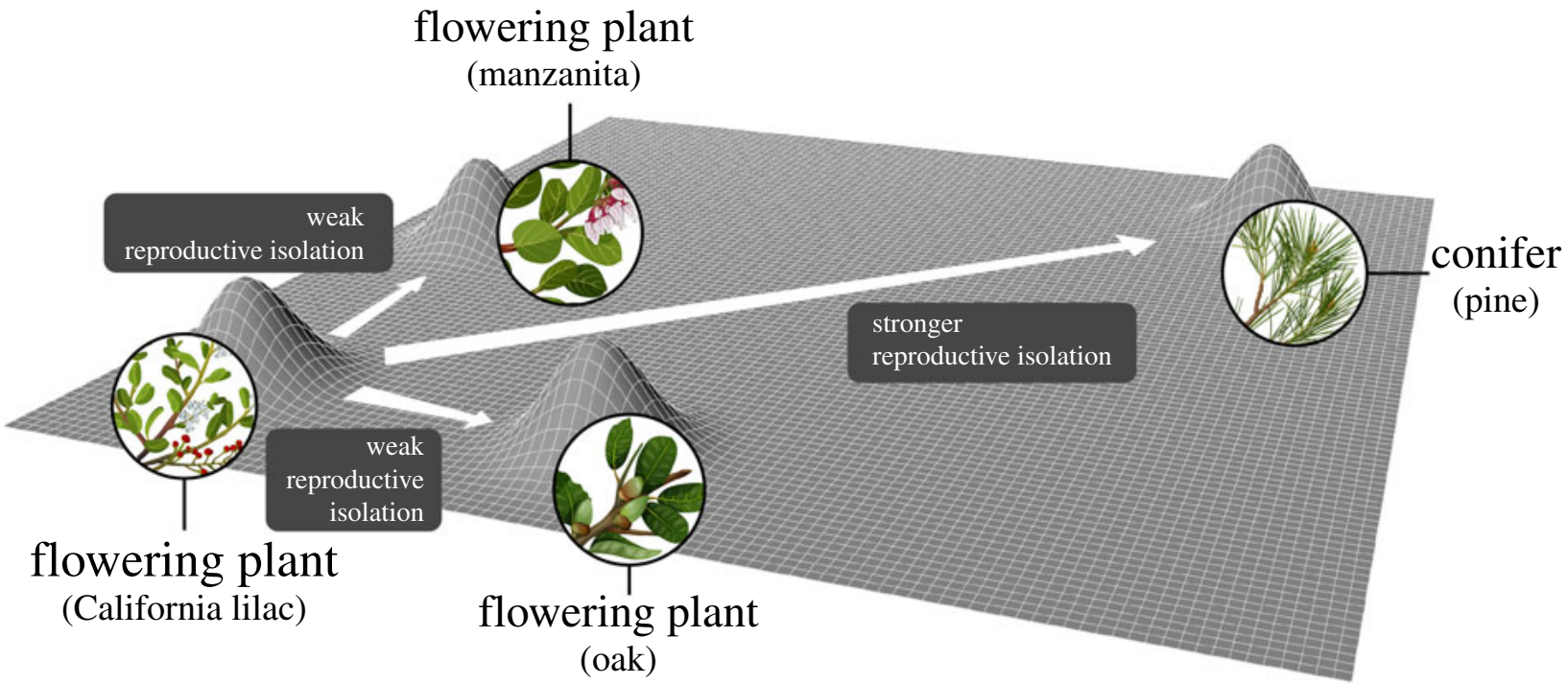
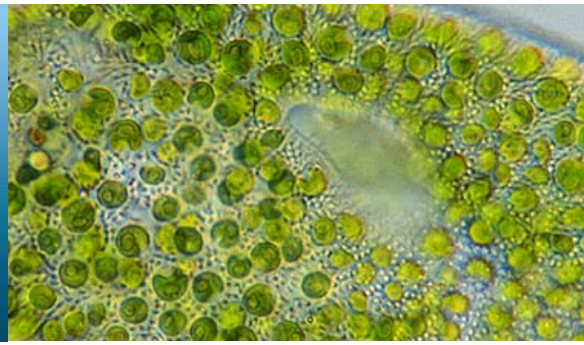


Muschick *et al.* 2020 *Phil Trans B*

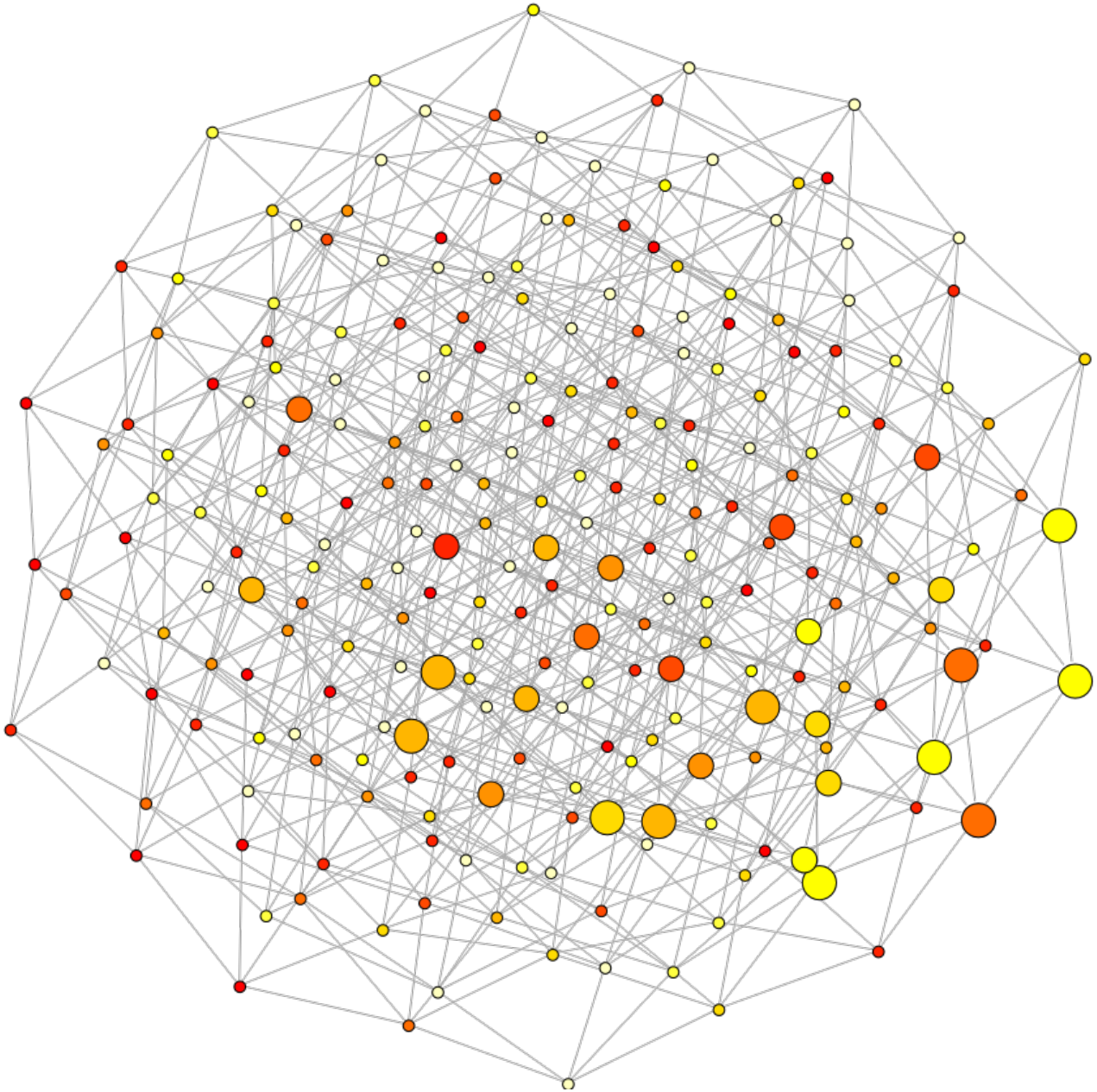
Genetic variation is the fuel for evolution




Punchline:

Rather than being a nuisance, complexity of process may provide resilience against the loss of genetic variation, modulating preference evolution



R. Villoutreix photo

“Even if it were possible to randomize the alleles at a single locus with respect to the rest of the genome … it would be a useless occupation.

Genes in populations do not exist in random combinations with other genes. …

context and interaction are not simply second-order effects [they are] … of the essence”

Lewontin 1974, pp. 318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