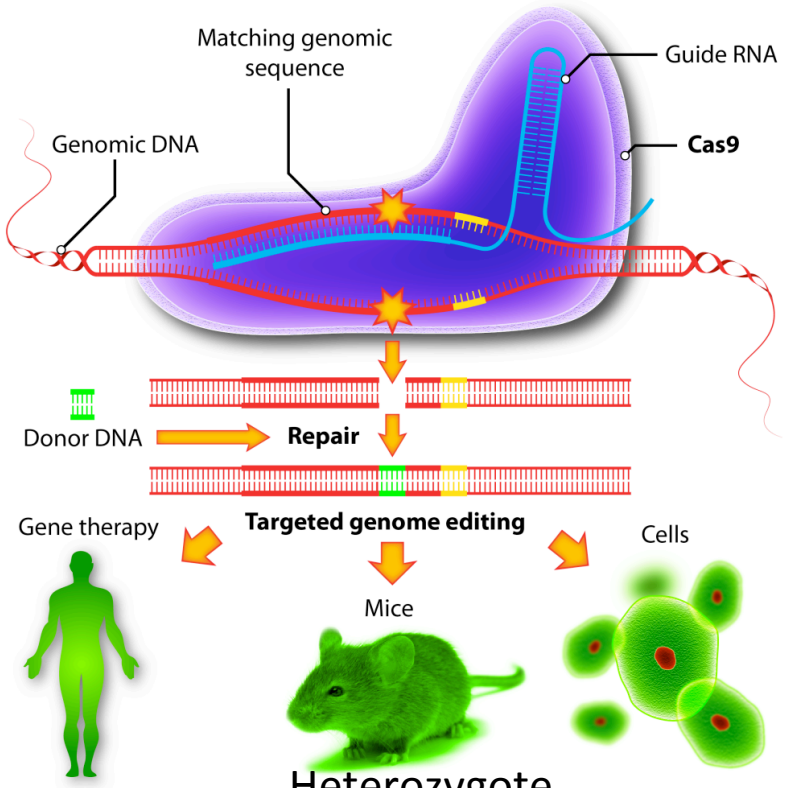


CRISPR-Cas9

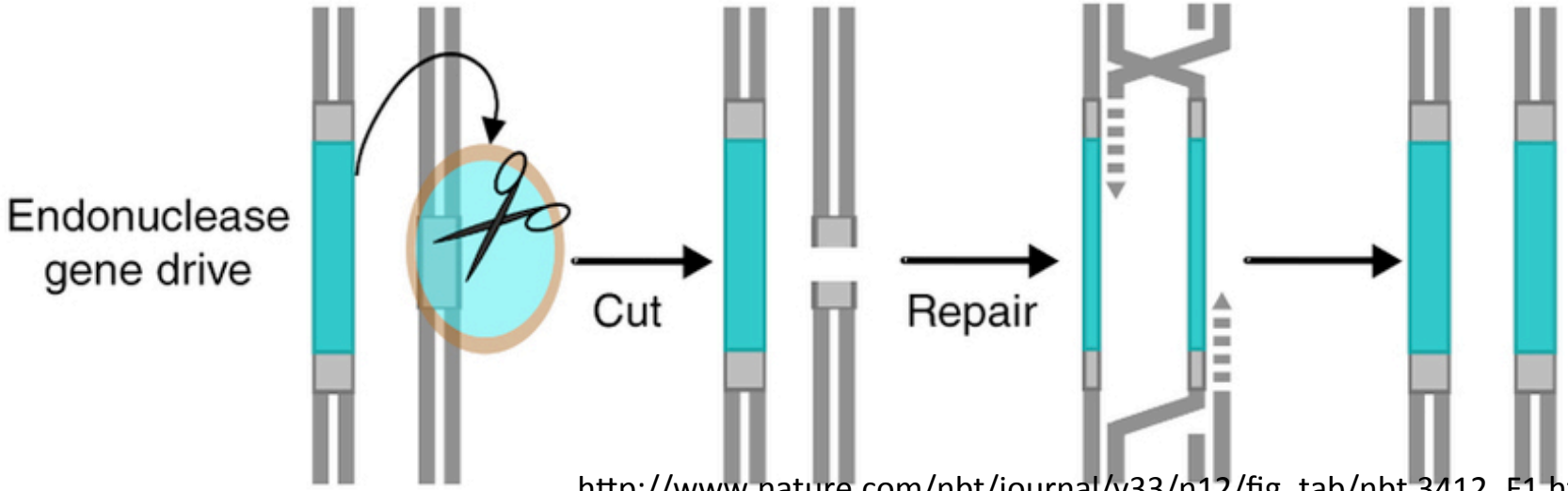
Very precise method for genome-editing

Emmanuelle Charpentier & Jennifer Doudna

Heterozygote for insertion

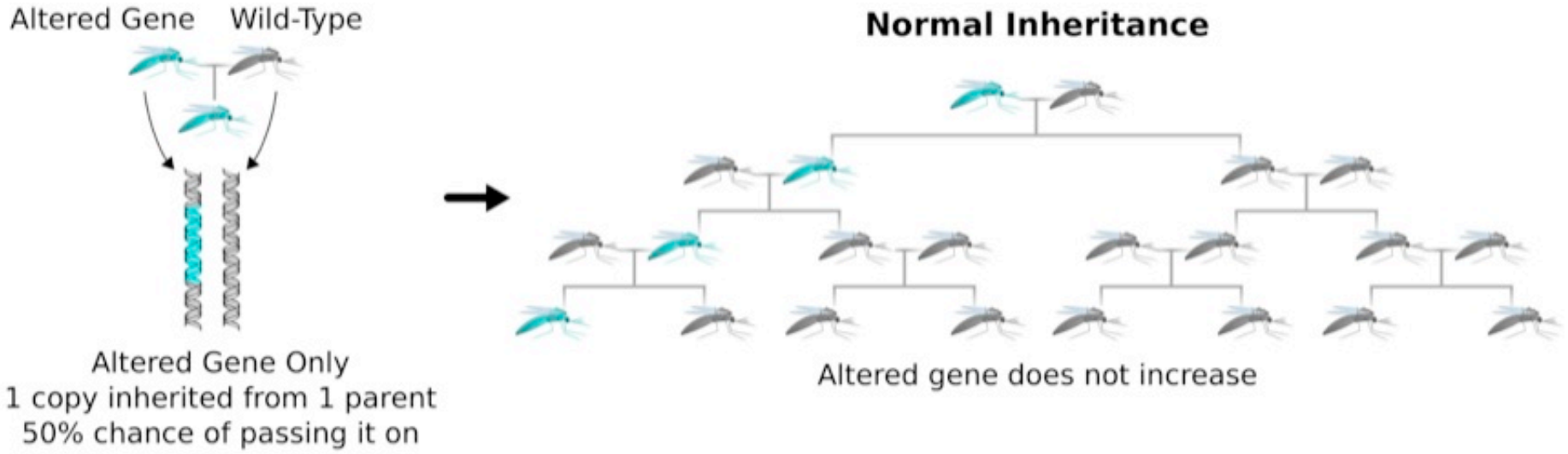
Homozygote for insertion

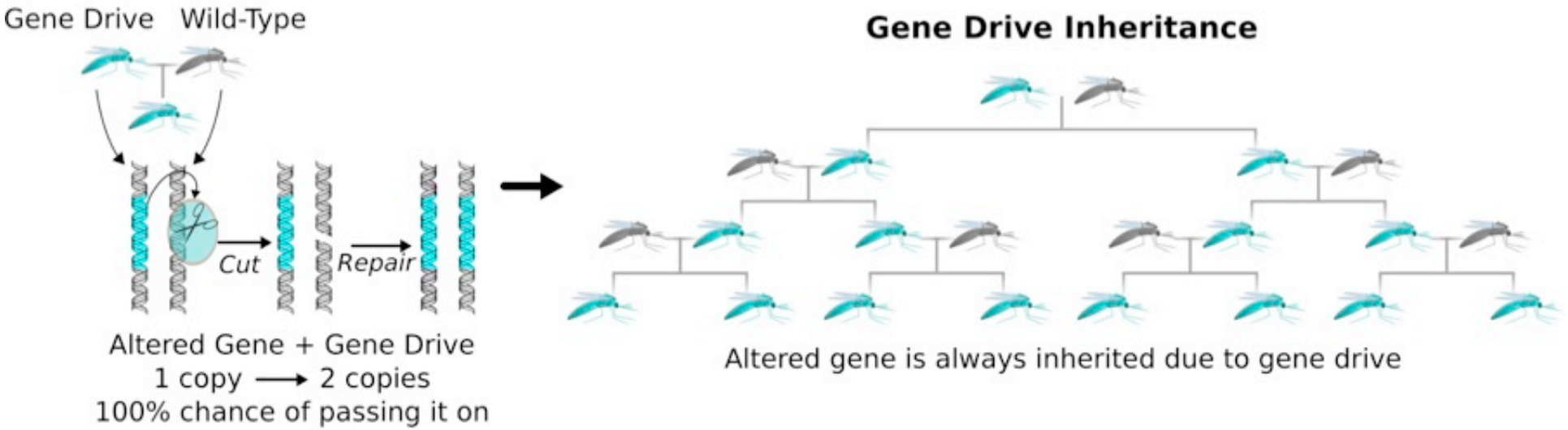
a



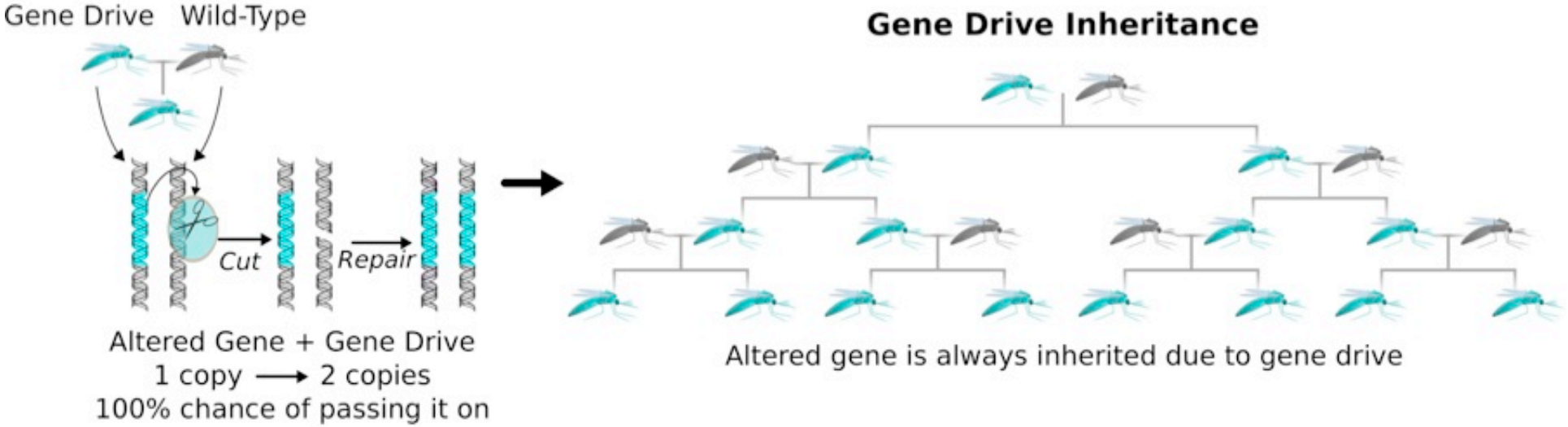
http://www.nature.com/nbt/journal/v33/n12/fig_tab/nbt.3412_F1.html

CRISPR-based Gene drive



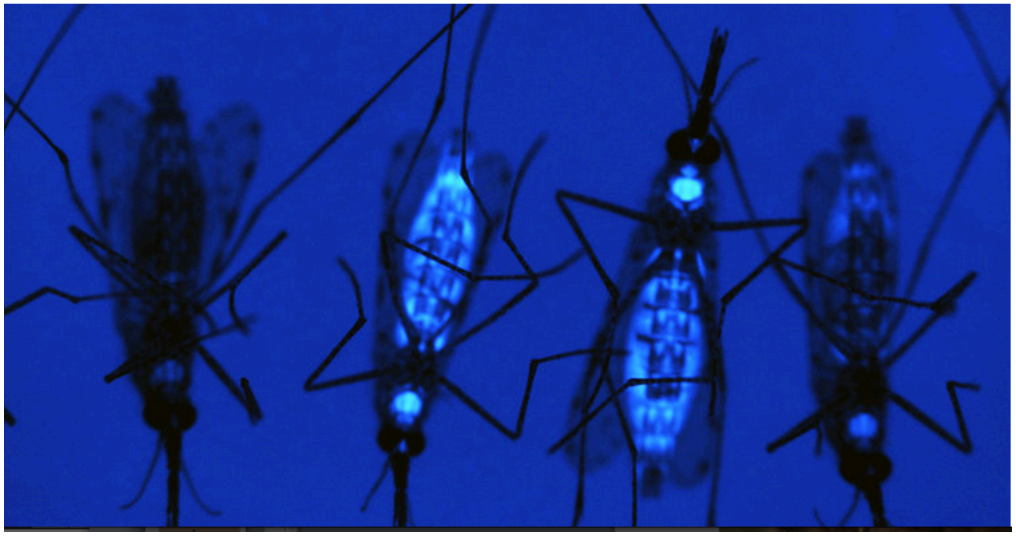


CRISPR-based Gene drive



Panel Endorses 'Gene Drive' Technology That Can Alter Entire Species

By AMY HARMON JUNE 8, 2016



mosquitoes infecting native Hawaiian birds with malaria

weed called Palmer amaranth that has become resistant to herbicides and a scourge for some farmers.

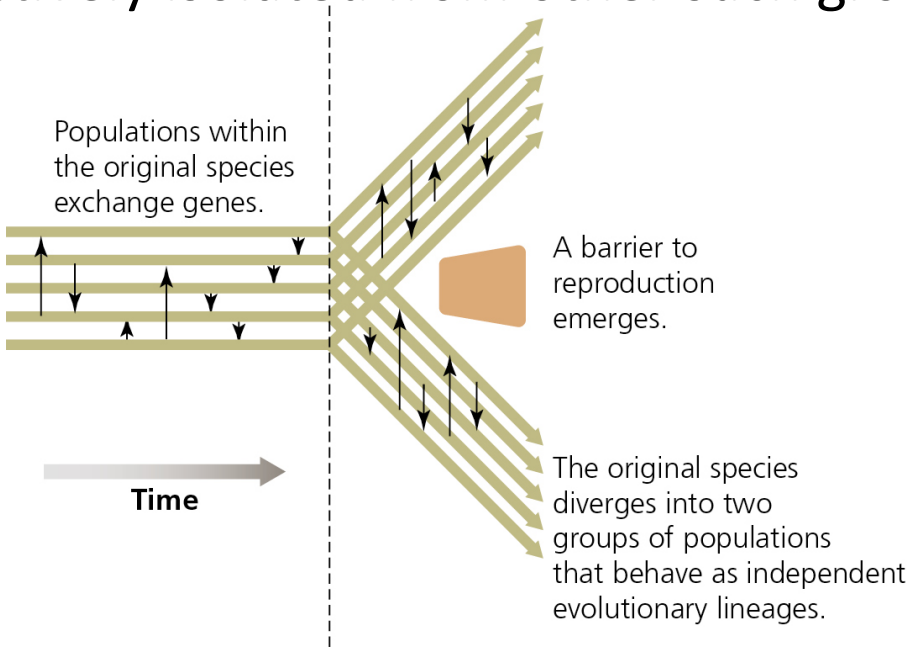
Mosquitoes (*Aedes aegypti*) to control zika/ malaria

Geographic population structure
&
Speciation

Speciation

Biological Species Concept:

species are groups of actually or potentially interbreeding populations *in nature*, reproductively isolated from other such groups.



- Speciation is the evolution of biological barriers to gene flow. Speciation forms a bridge between popgen & macroevol
- **Species are set of alleles/traits held in linkage disequilibrium through evolution of biological barriers to gene flow**

Speciation consists of the evolution of biological barriers to gene flow

Pre-mating isolation (Organisms occur in the same area but don't mate)

- Potential mates don't meet:
  - Different habitats
  - Different mating seasons/times
- Potential mates meet but don't mate:
  - Different mating behavior in animals
  - Different pollinators in plants

Postmating, prezygotic (Potential mates try to mate but can't form a zygote)

- Incompatible genitalia
- Incompatible gametes

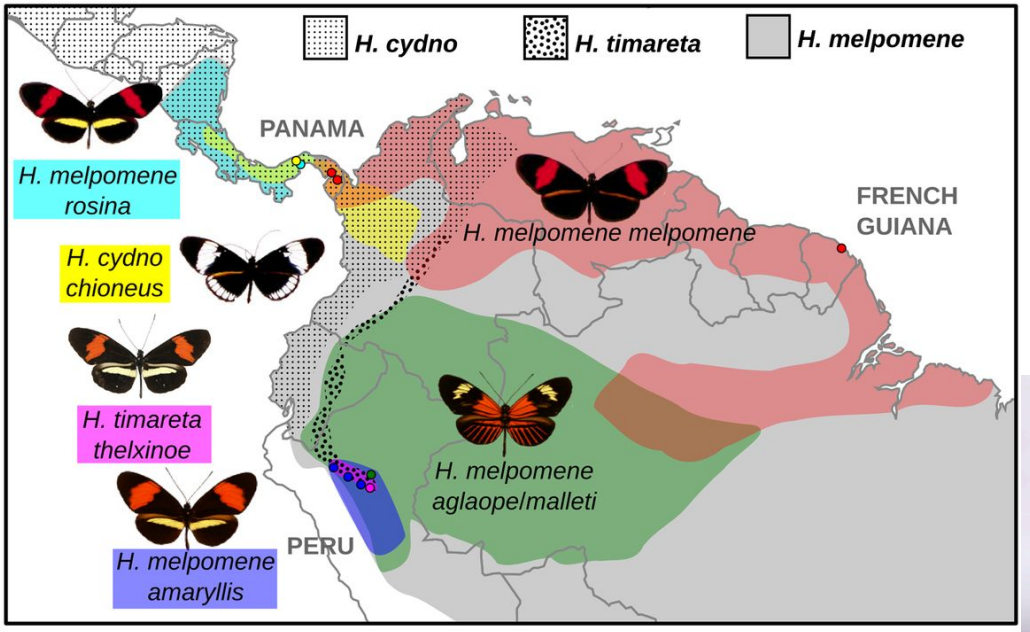
Postzygotic isolation (Hybrids are formed but have low fitness)

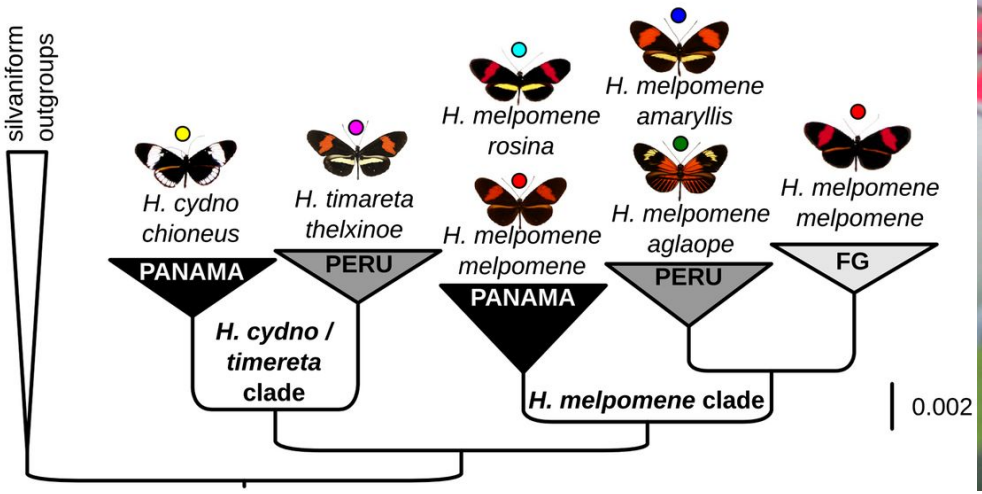
- "Intrinsic" mechanisms
  - Hybrid lethality
  - Hybrid sterility (physiological)
- "Extrinsic" mechanisms
  - Ecological: hybrids don't fit into either ecological niche
  - Mate recognition: mating behavior not appropriate for either species

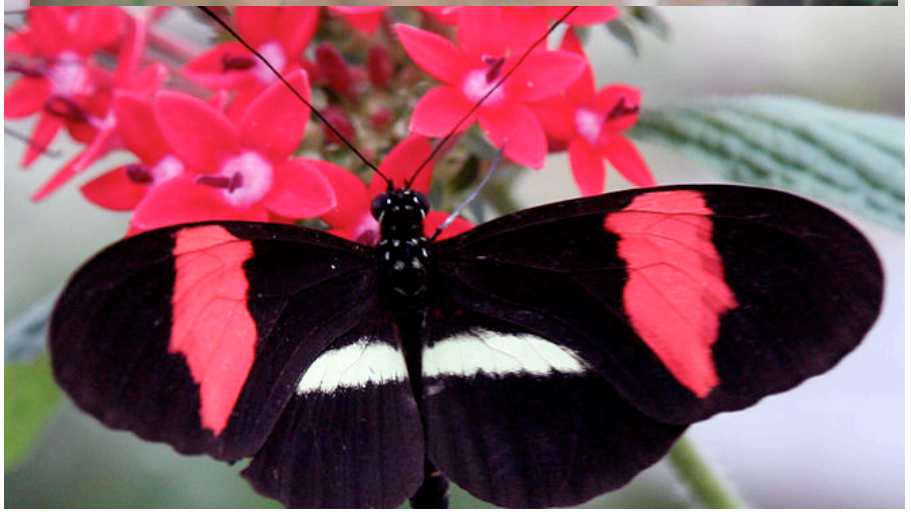
Geographic population structure

- Low levels of migration between populations allow LD to be maintained even between non-epistatic (or non-assortative mating) combinations.
  - Allows build up of locally adaptive alleles, forming locally adapted forms (ecotypes/races).
  - Neutral differentiation

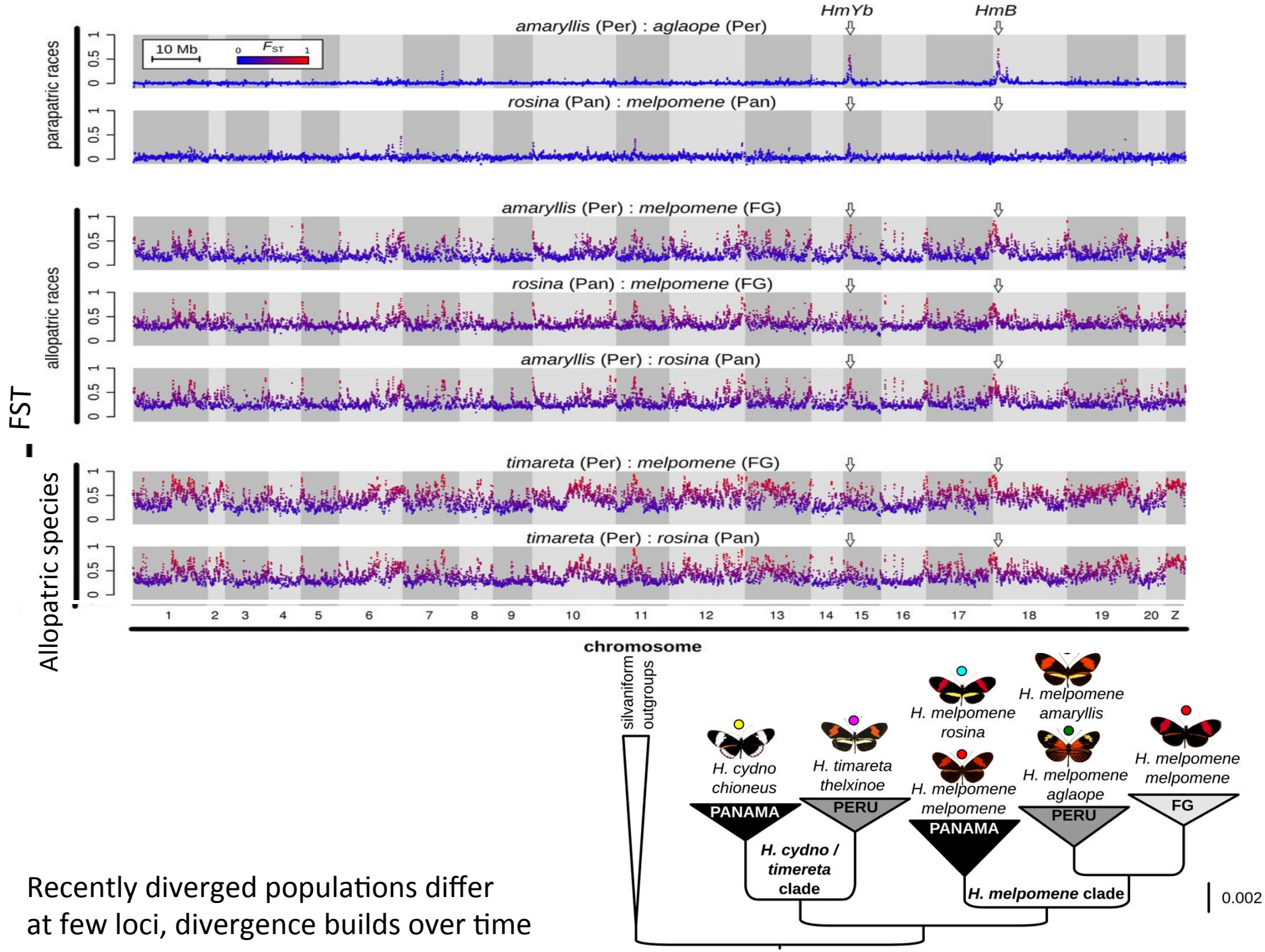
- Local adaptation, through selection against migrants, can further lower effective migration rate







"Heliconius Melpomene Rosina" by Wikifan75 - Own work. http://commons.wikimedia.org/wiki/File:Heliconius_Melpomene_Rosina.jpg



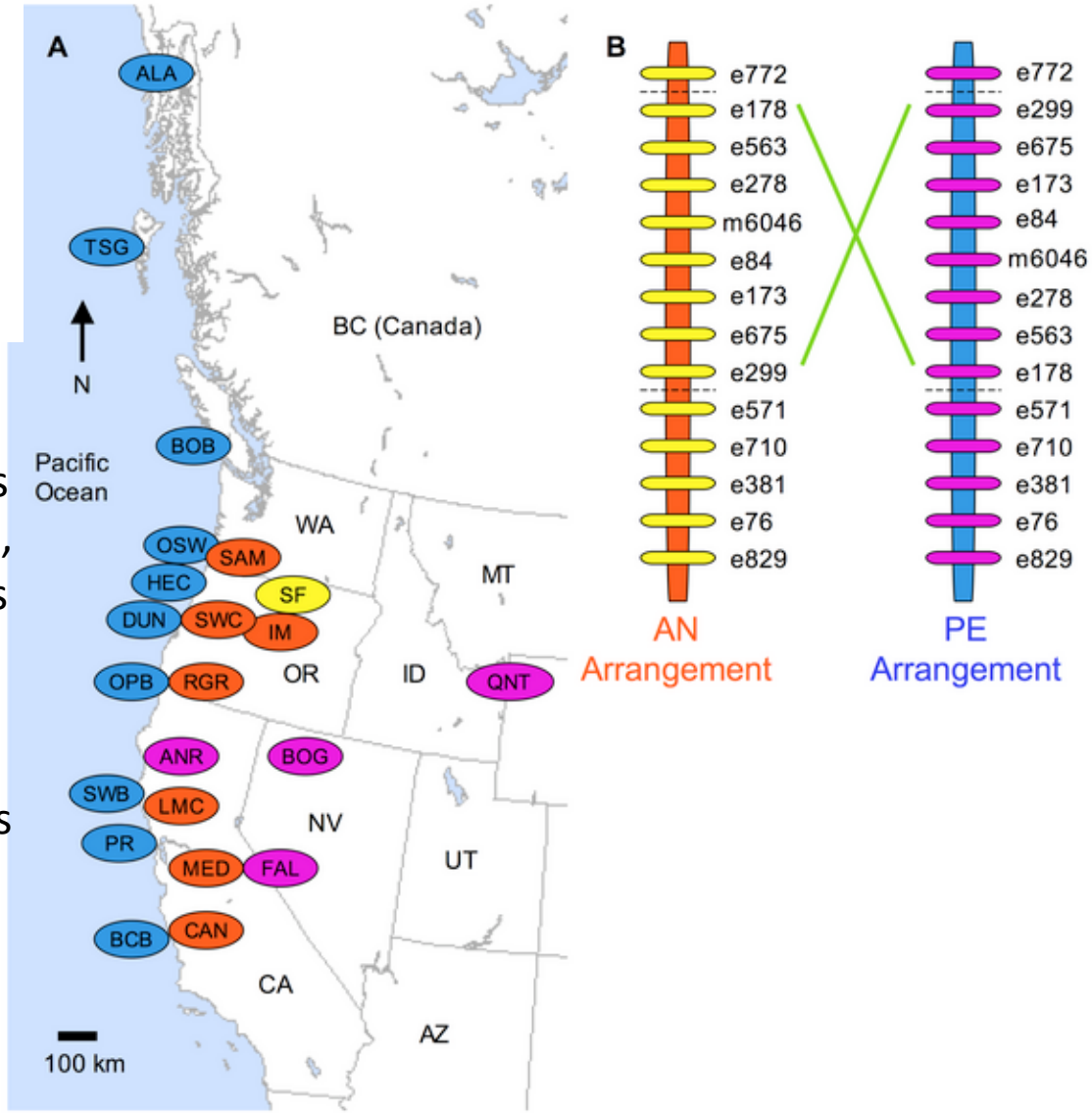
Recently diverged populations differ at few loci, divergence builds over time

coastal perennial and inland annual

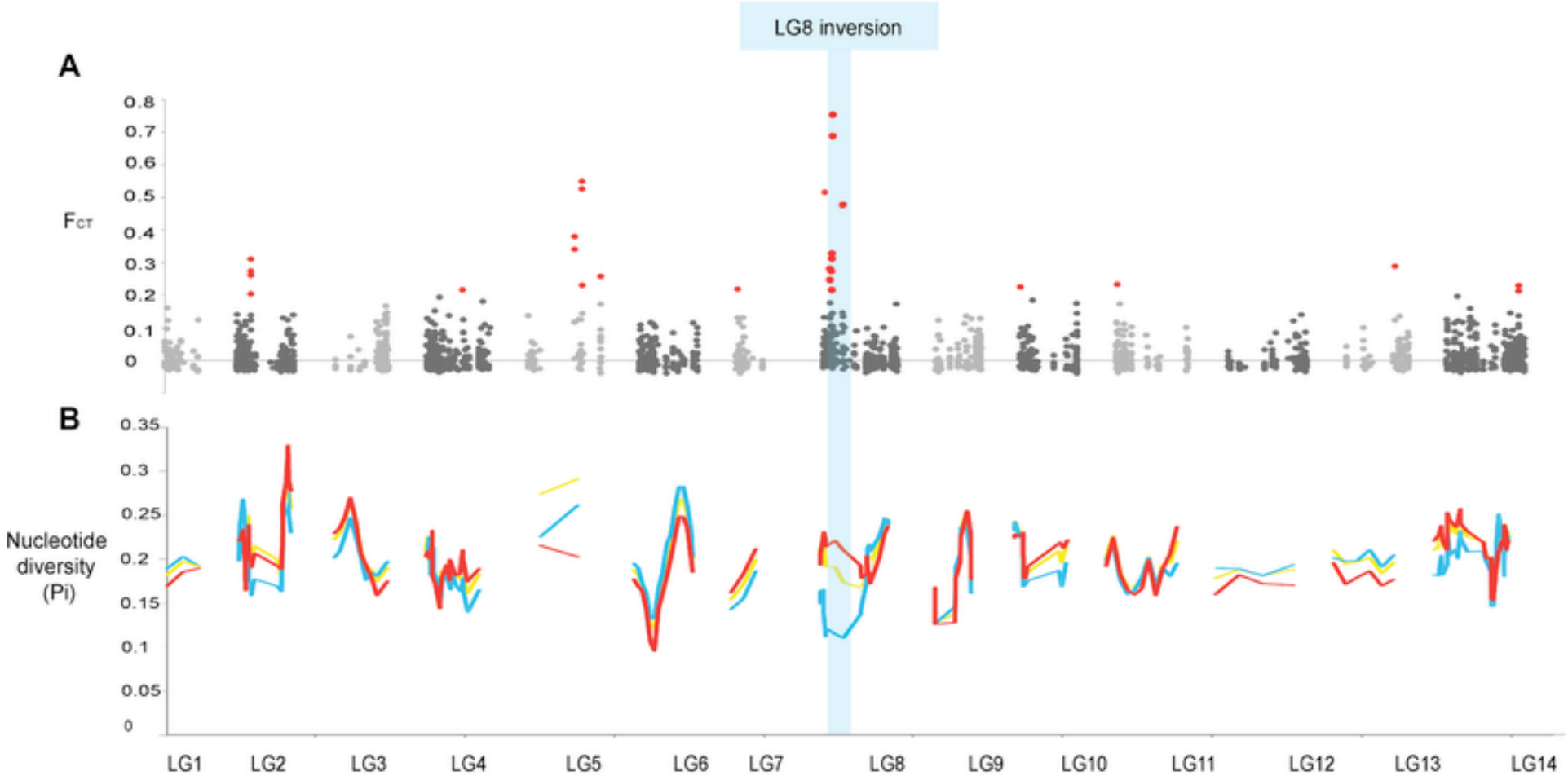
A Widespread Chromosomal Inversion Polymorphism Contributes to a Major Life-History Transition, Local Adaptation, and Reproductive Isolation. 2010 Lowry & Willis

coastal perennials (blue), inland annuals (orange), and inland perennials (purple), as well as obligate self-fertilizing species M. nasutus (yellow)

Local adaptation mediated by inversions
Also seen in Drosophila & Mosquitos
And likely many other species

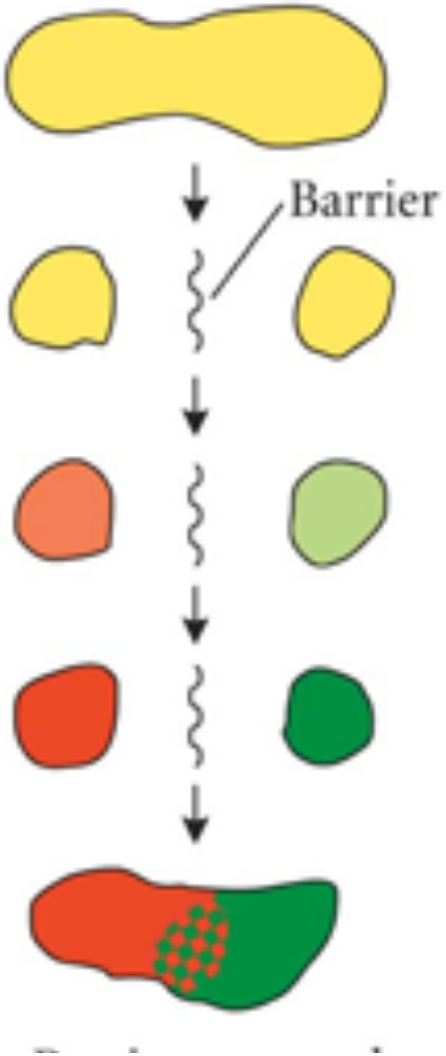


Pairwise nucleotide divergence between ecotypes (D_{XY}) is shown in yellow, nucleotide diversity in annuals (π_A), perennials (π_P) in blue.



Twyford & Friedman. **Adaptive divergence in the monkey flower *Mimulus guttatus* is maintained by a chromosomal inversion**

Allopatric speciation is potentially easy



No (low) interbreeding due to geographic barriers

Anagenesis proceeds independently

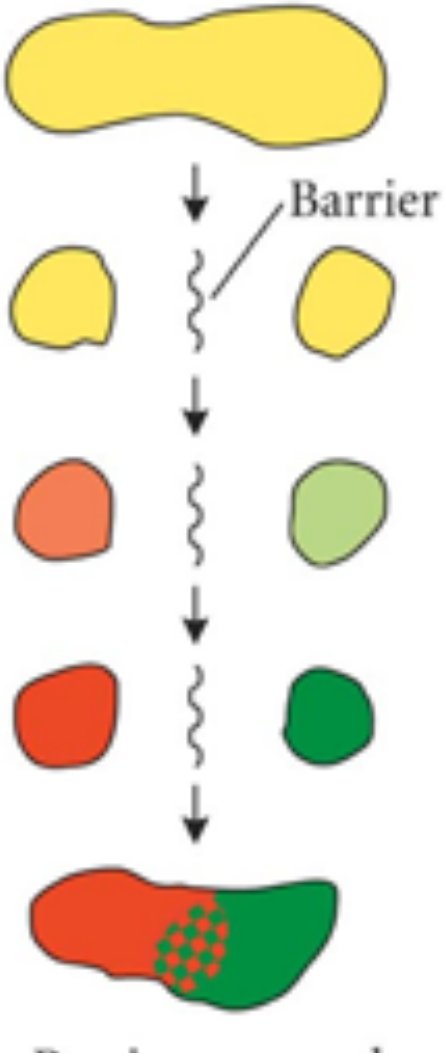
Barriers to reproduction evolve as a passive side effect of anagenesis

This may happen rapidly if ecology of the populations differs

The difficulty with sympatric speciation

- Disruptive selection on phenotype has to be very strong
  - i.e. selection against intermediates has to be strong
- And:
- Individuals must mate assortatively with others of similar phenotype.
- The process is helped if alleles have a pleiotropic effect on both phenotype and choice
- Or if they are closely genetically linked.
- …But if they are genetically closely linked then gene flow can occur in rest of genome

Allopatric speciation is potentially easy



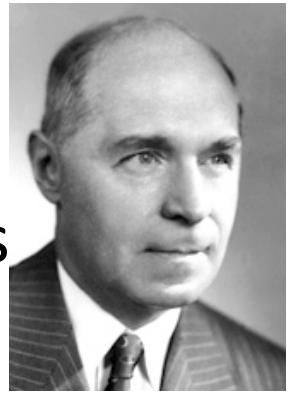
No (low) interbreeding due to geographic barriers

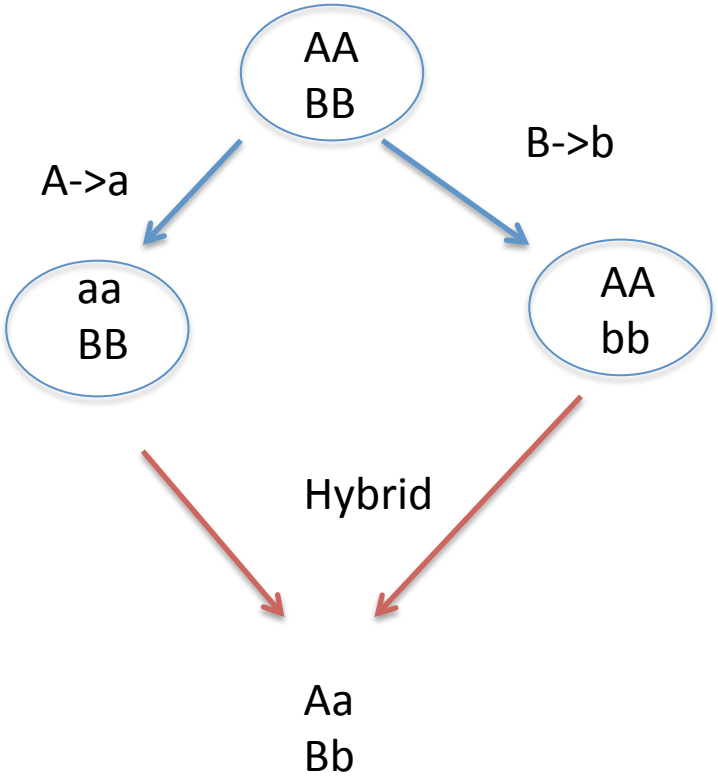
Anagenesis proceeds independently

Barriers to reproduction evolve as a passive side effect of anagenesis

This may happen rapidly if ecology of the populations differs

Isolation allows the evolution of Dobzhansky-Muller (intrinsic hybrid sterility/inviability) Incompatibilities





One locus model does not work.

Substitutions at two or more loci can generate incompatible genotypes

These have never been tested in the background of the other

Such incompatibilities are termed Dobzhansky-Muller Incompatibilities (DMIs)
(This is an example of epistasis)

Substitutions accumulate linearly, but DMI pairs accumulate faster than that

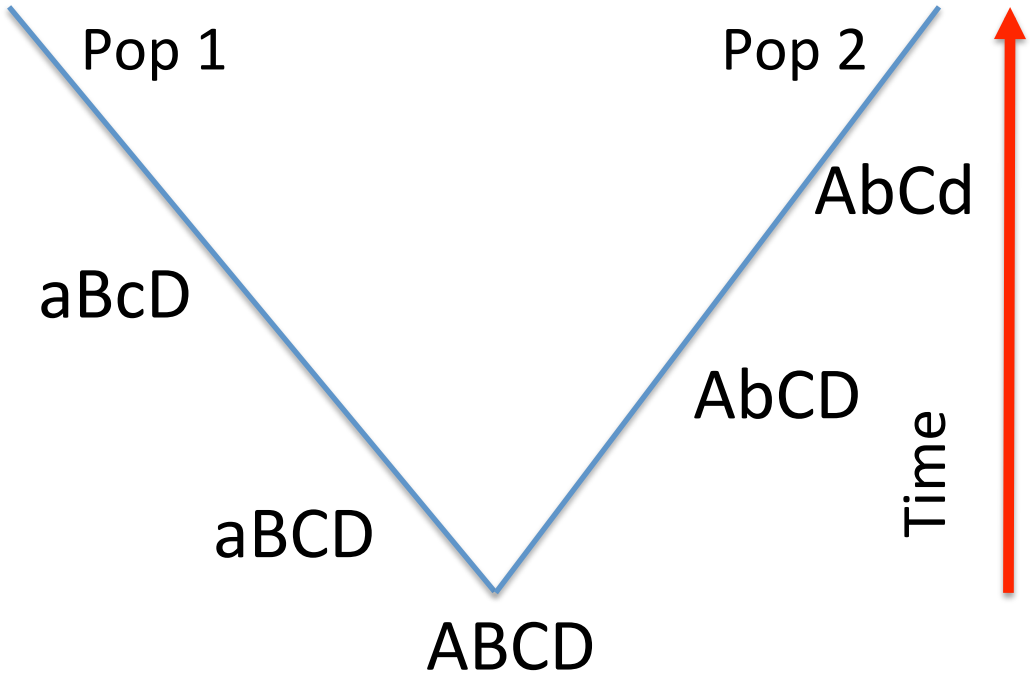
Substitutions	DMIs
0	0
1	0
2	1
3	3
4	6

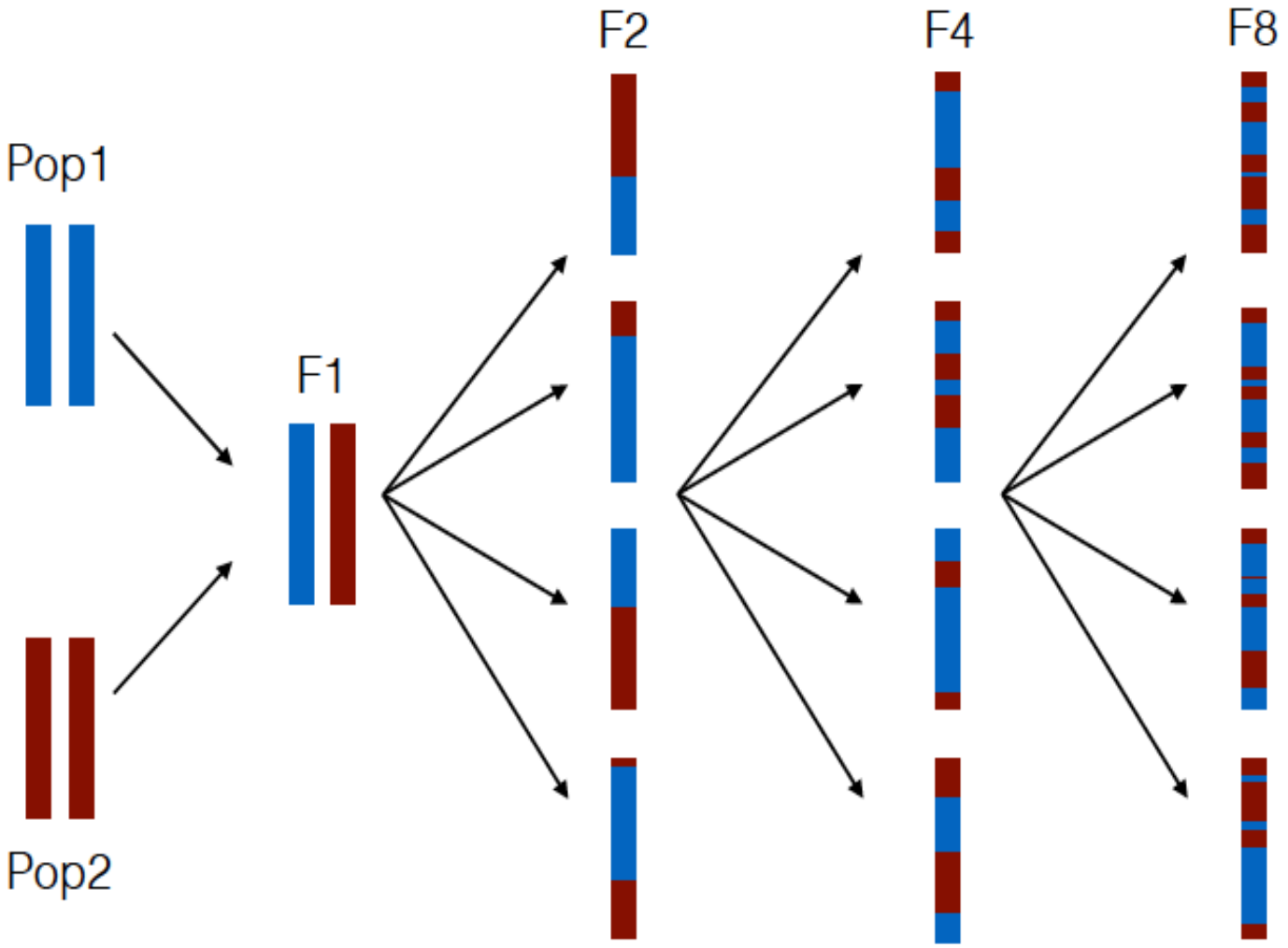
d fixes in pop 2,

Potential DMIs = 6 …

(c & b, c & A, b & a,

d & c, d & a, d & B)



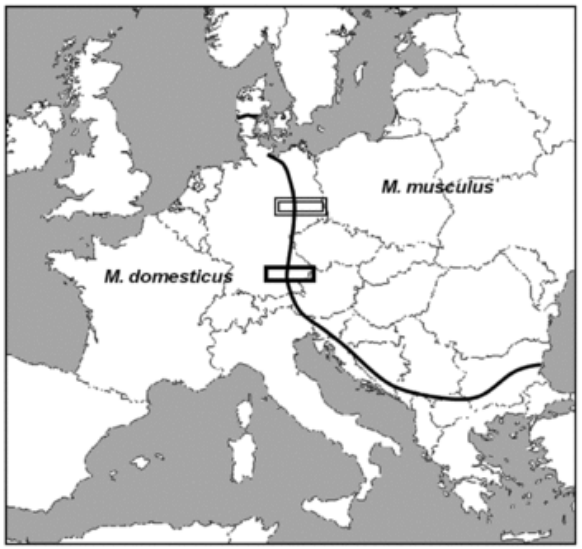


Adapted from Buerkle and Lexer 2008

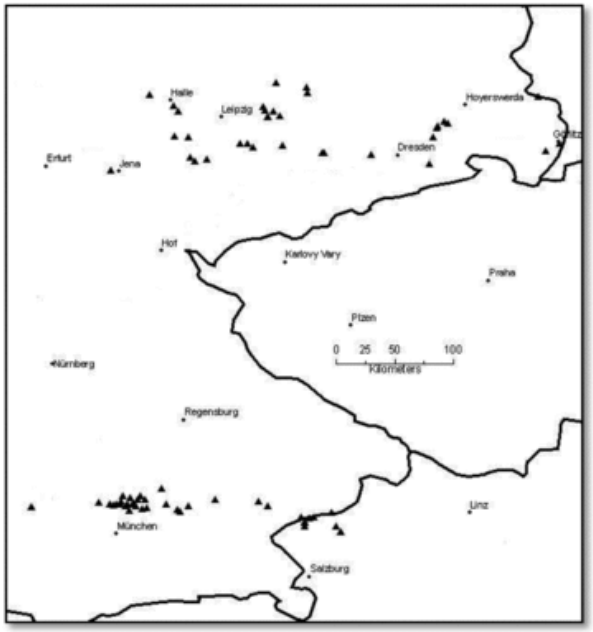
Slide from Alisa Sedghifar

House mouse
Hybrid zone

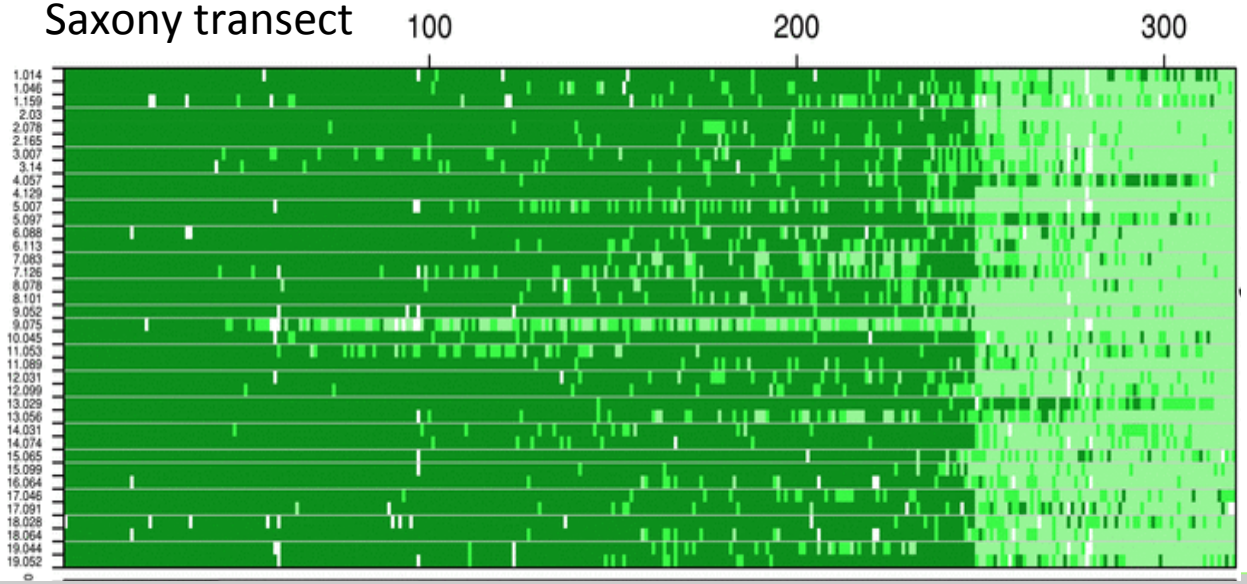
A



B

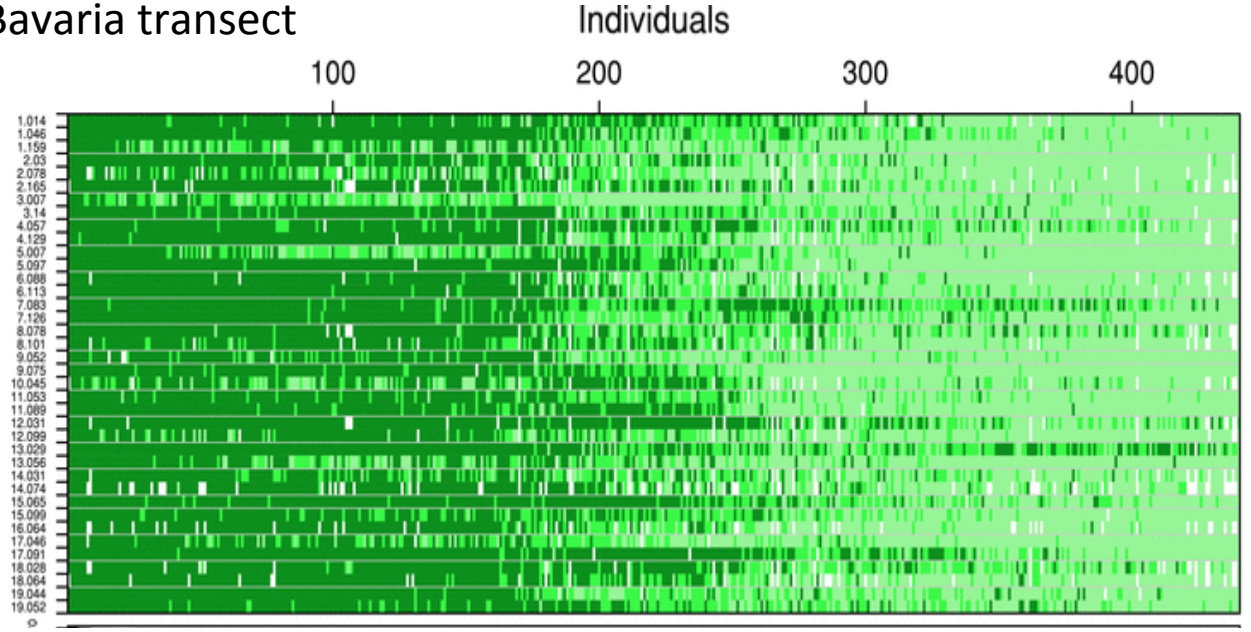


Saxony transect



homozygotes M. domesticus alleles, homozygotes for M. musculus heterozygotes

Bavaria transect



THE VARIABLE GENOMIC ARCHITECTURE OF ISOLATION BETWEEN HYBRIDIZING SPECIES OF HOUSE MICE

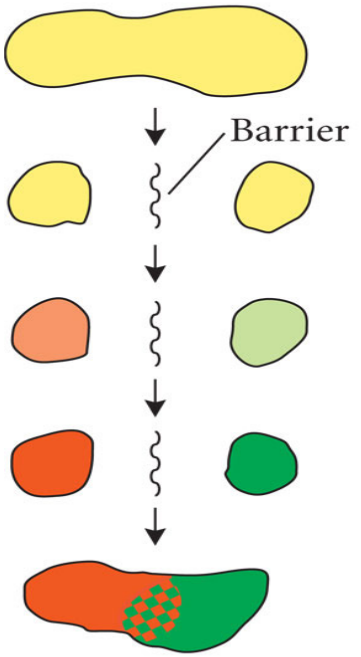
Katherine C. Teeter ✉, Lisa M. Thibodeau, Zachariah Gompert, C. Alex Buerkle, Michael W. Nachman, Priscilla K. Tucker

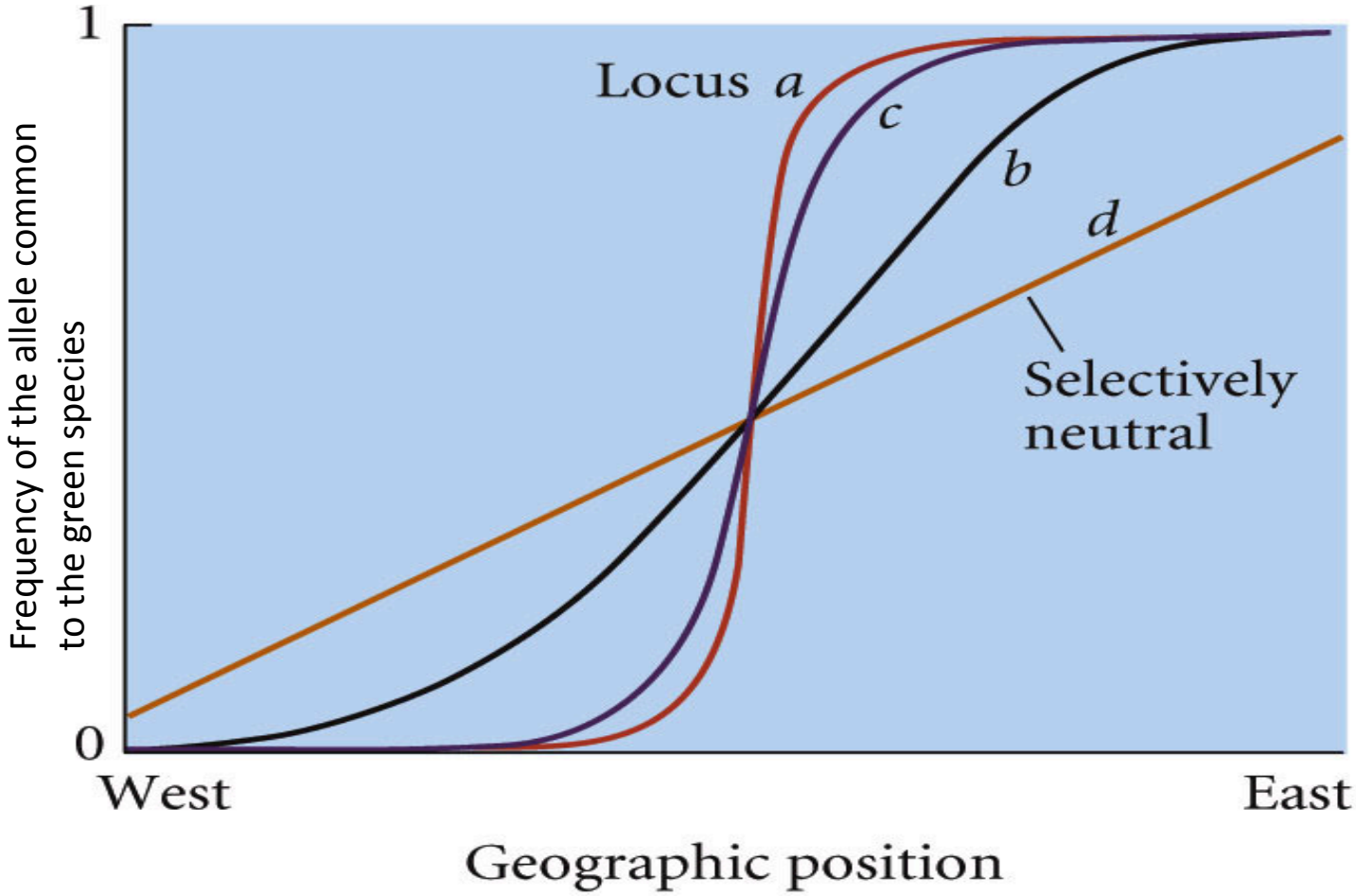
Hybrid zones can form when once isolated populations spread back into secondary contact.

Gene flow (migration) moves alleles between populations

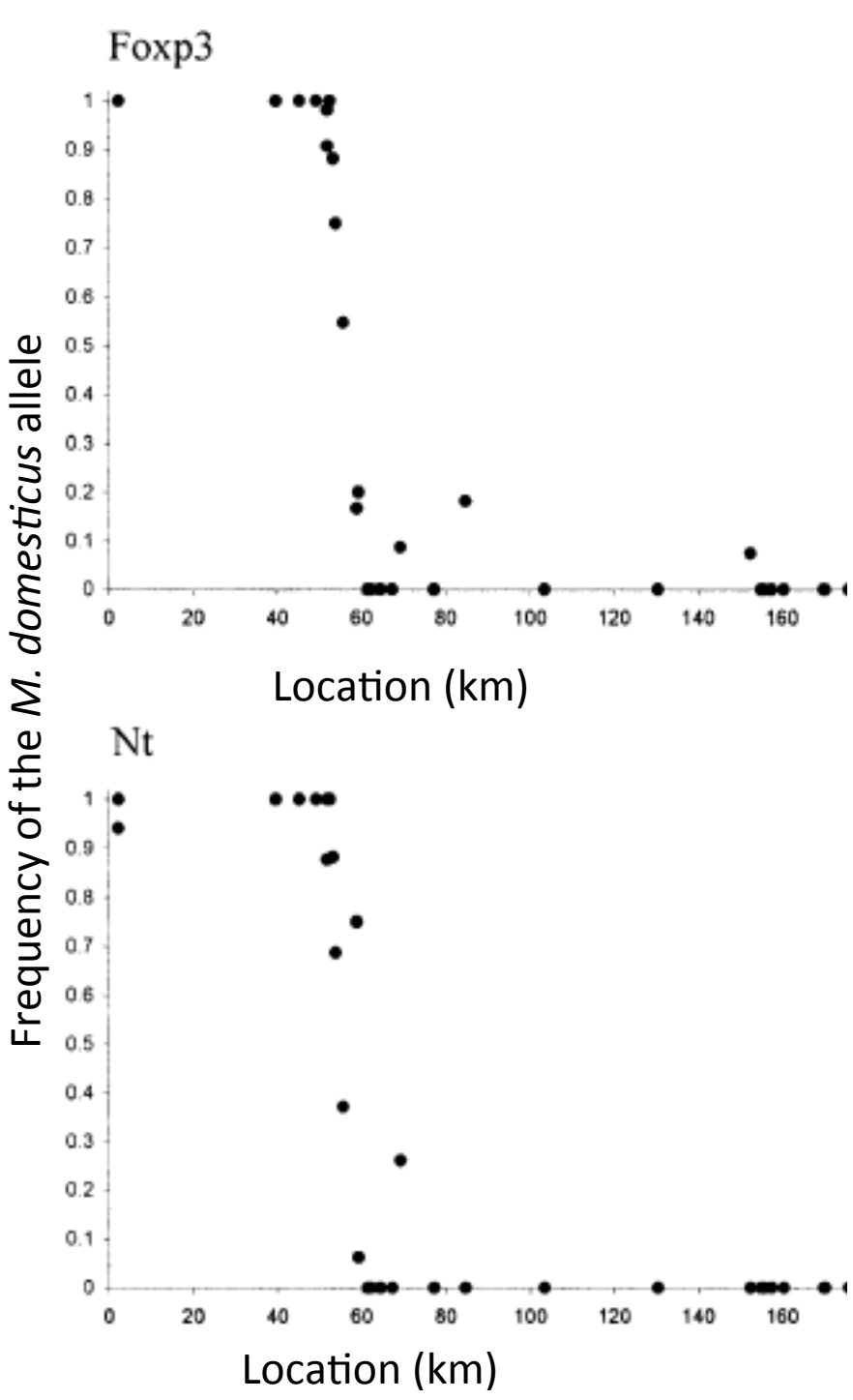
Selection acts acts against this flow at loci tightly linked to genes

Involved in reproductive isolation





***EVOLUTION 3e*, Figure 18.1**



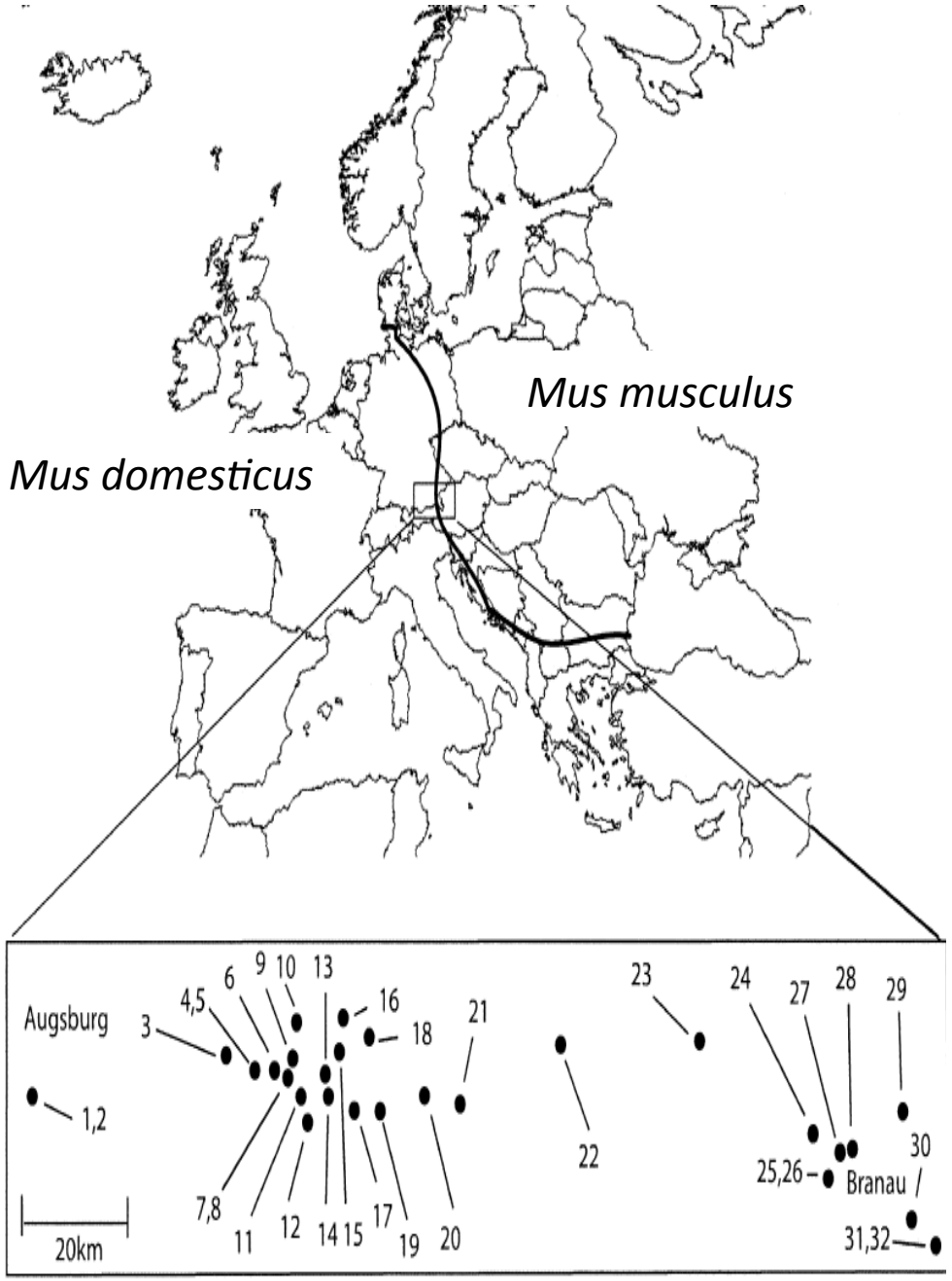
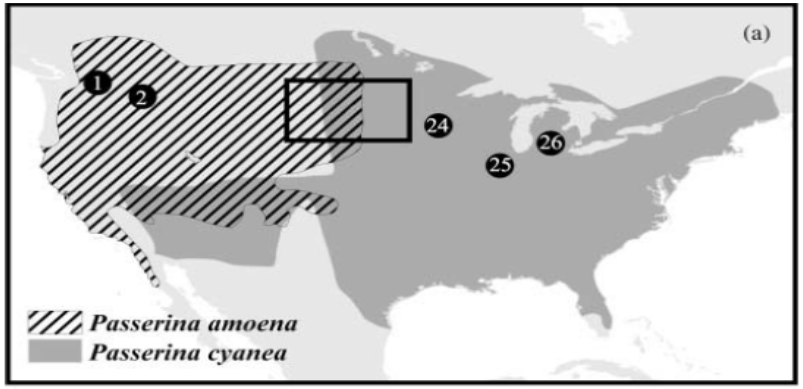
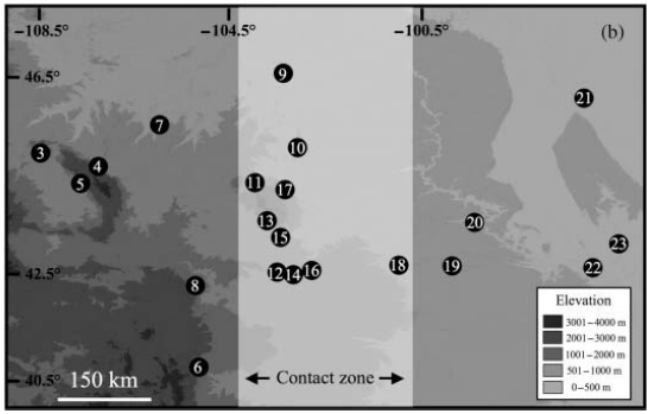
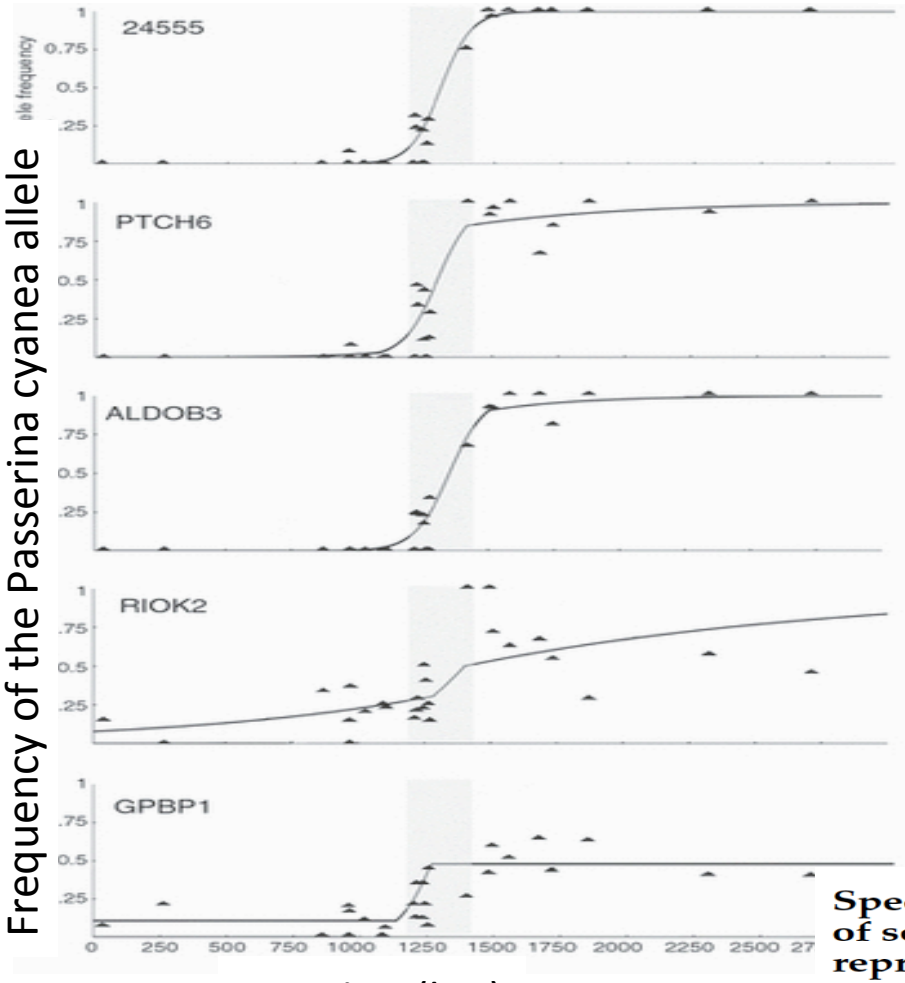


FIG. 1. Map of collecting localities along a transect through the hybrid zone between *Mus domesticus* and *M. musculus* in so Germany and western Austria. Locality numbers correspond to those in Table 1. The dark line shows the approximate position hybrid zone throughout Europe (modified from Sage et al. 1993).





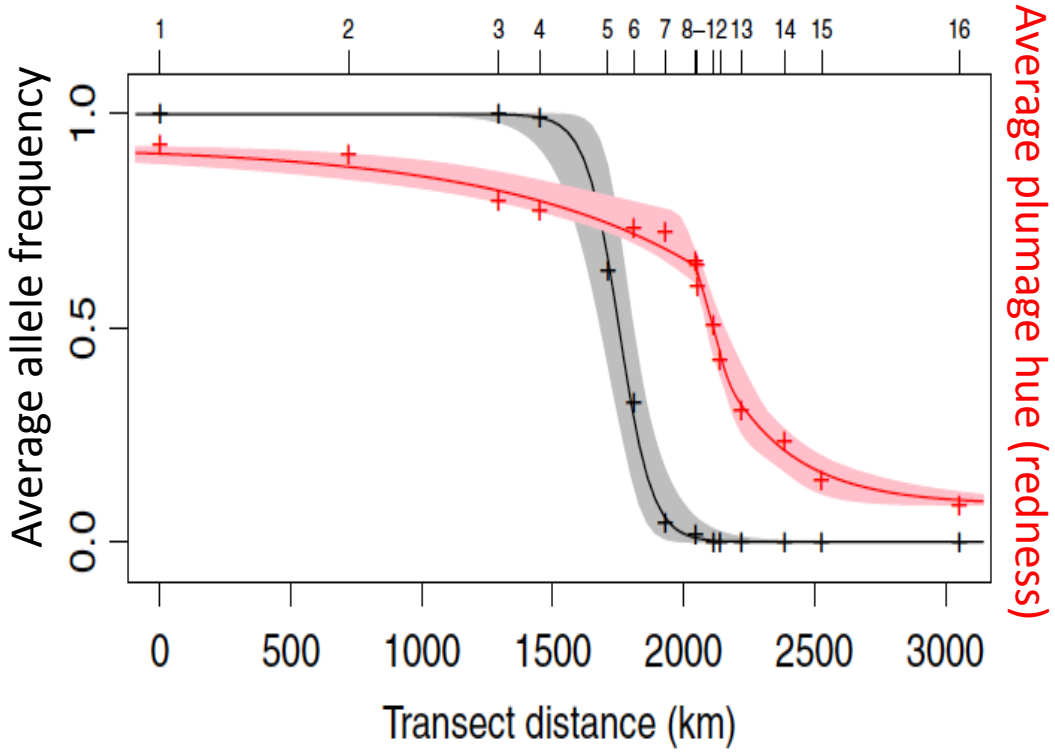


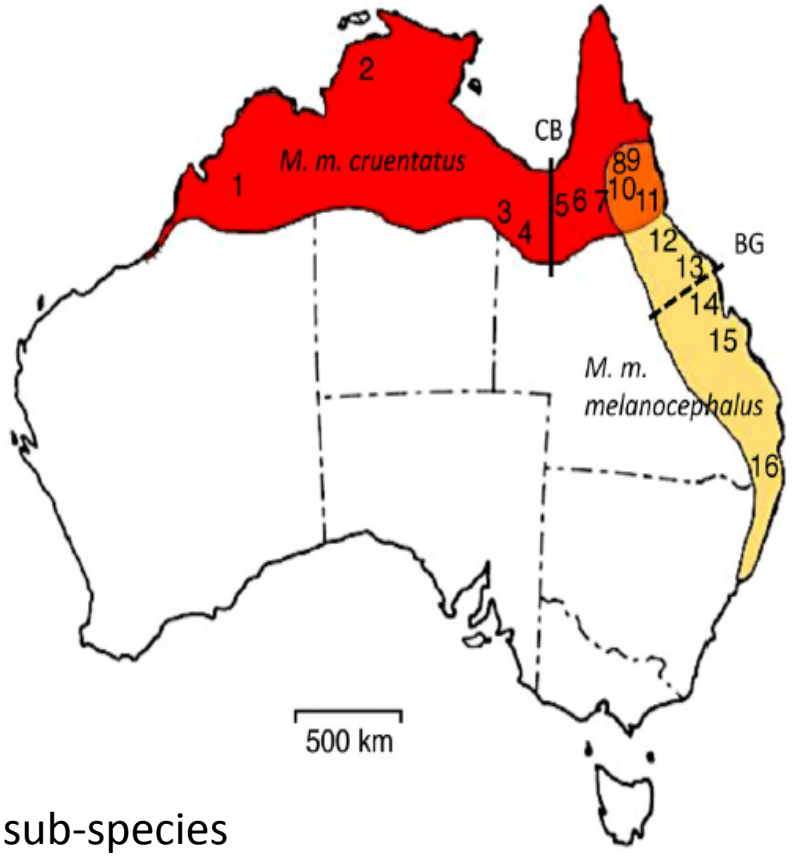
Frequency of the Passerina cyanea allele

Location (km)

Speciation in *Passerina* buntings: introgression patterns of sex-linked loci identify a candidate gene region for reproductive isolation

MATTHEW D. CARLING* and ROBB T. BRUMFIELD

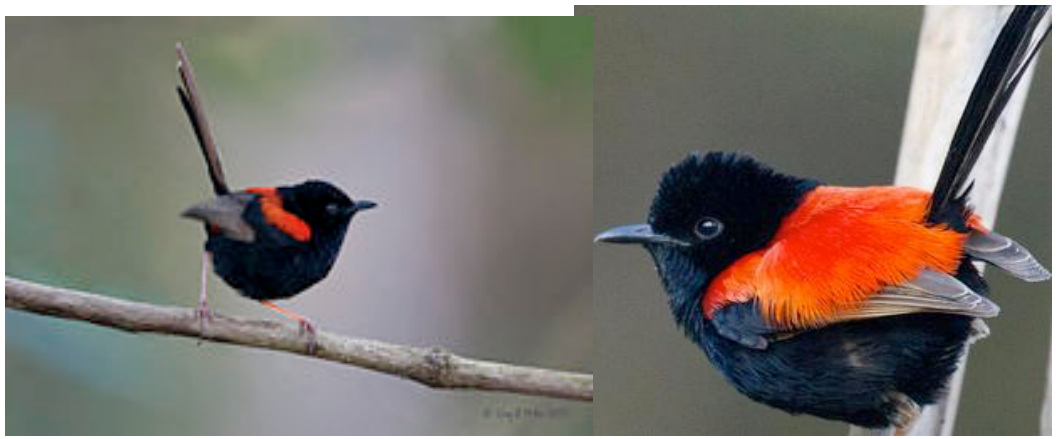




Two red-backed fairy-wren (*Malurus melanocephalus*) sub-species

GENOMIC AND MORPHOLOGICAL ANALYSIS OF A SEMIPERMEABLE AVIAN HYBRID ZONE SUGGESTS ASYMMETRICAL INTROGRESSION OF A SEXUAL SIGNAL

Daniel T. Baldassarre,[1,2,3] Thomas A. White,[4] Jordan Karubian,[5] and Michael S. Webster[1,2]



Selection can sometimes favour the Introgression of particular alleles across Hybrid zones