

Concepts, islands & continuums: a perspective on speciation genomics

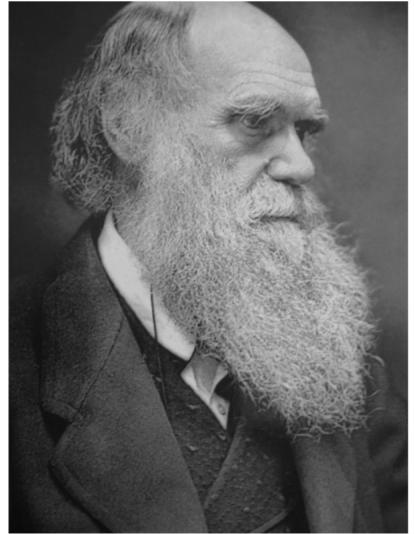


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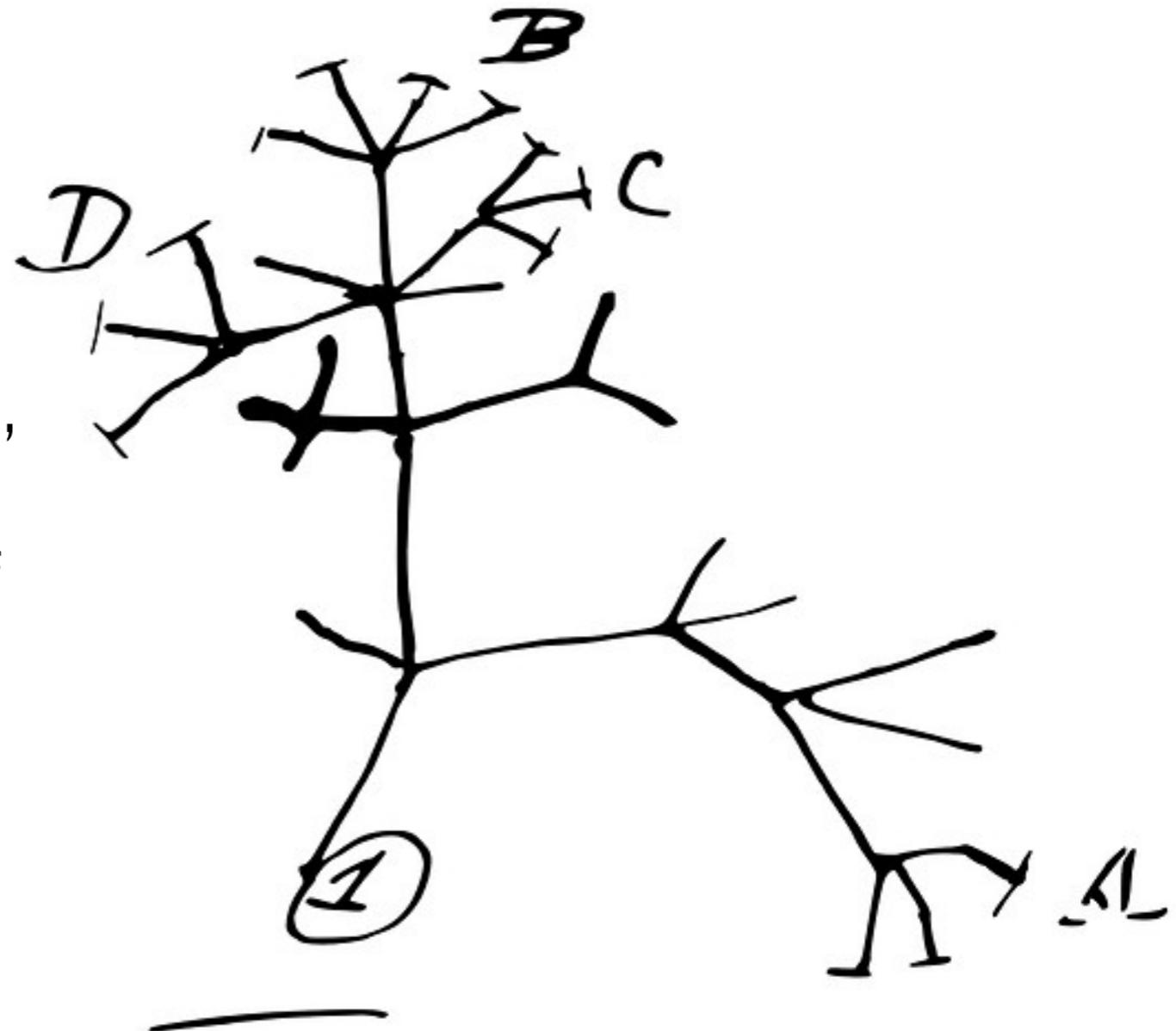
Darwin and the origin



“...that mystery of mysteries...”

Charles Darwin (1859) *The Origin of Species*

I think



Species concepts and the modern synthesis

“Species are groups of interbreeding natural populations... reproductively isolated from other such groups”

Ernst Mayr (1942) *Systematics and the Origin of Species*



“[The] existence of discrete groups... constitutes evidence that some mechanisms... [isolate] them”

Theodosius Dobzhansky (1937) *Genetics and the Origin of Species*

Hybrid zones and gene flow

“Narrow regions in which genetically distinct organisms meet, mate and produce hybrids”

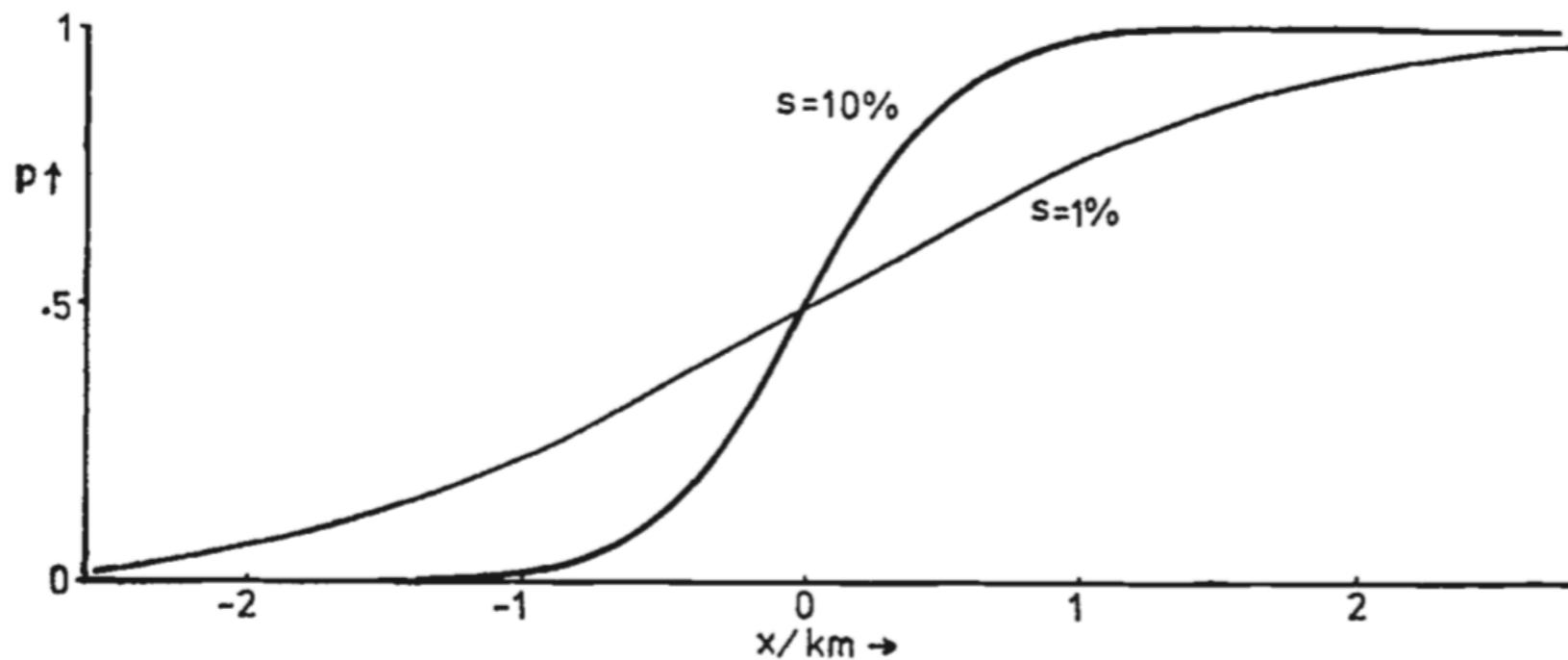


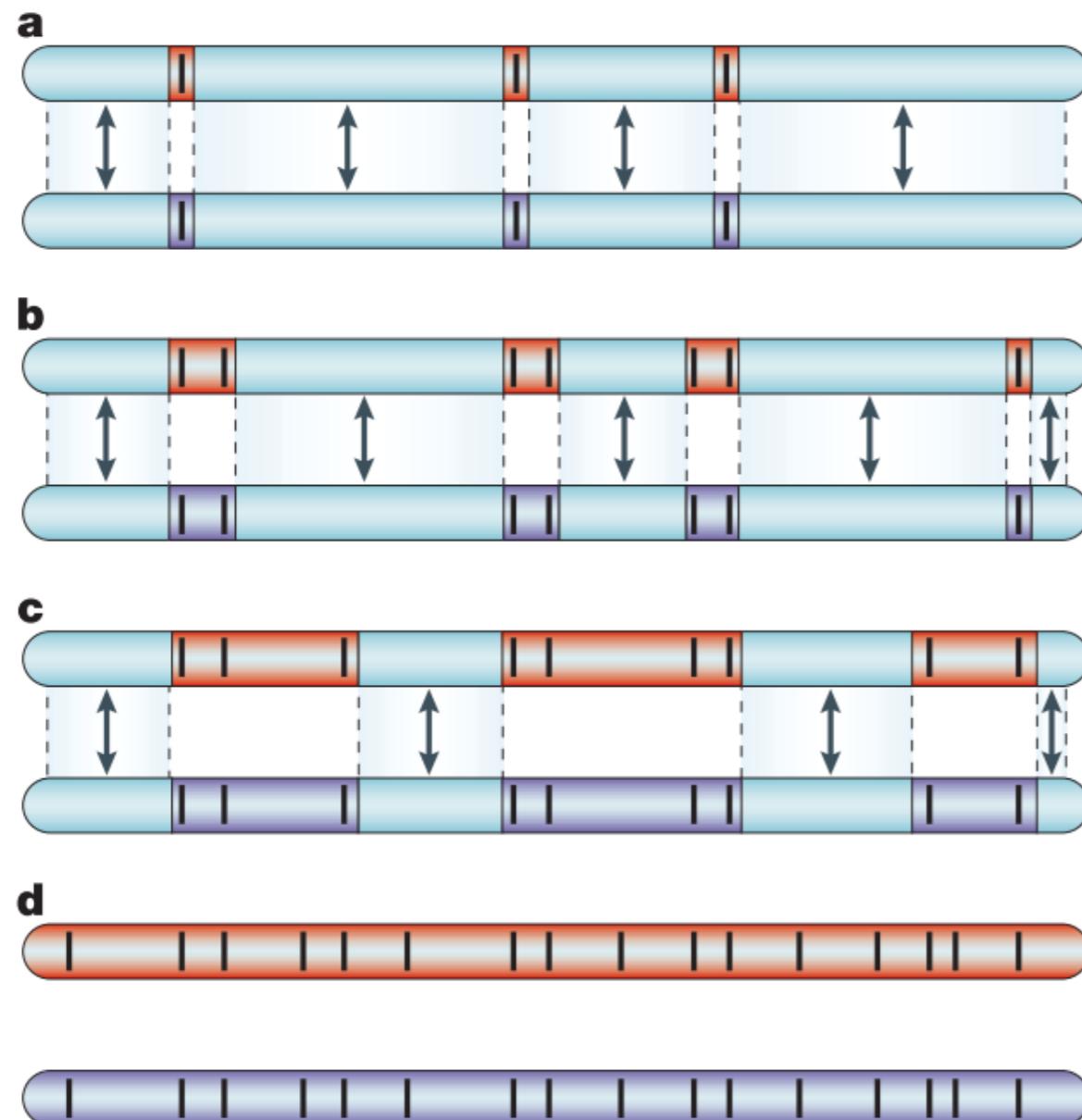
FIG. 1.—Hybrid zones produced by selection against heterozygotes;
dispersal $\sqrt{m} = 112 \text{ m.gen.}^{-\frac{1}{2}}$

Barton (1979) **Heredity**

“Maintained by a balance between dispersal and selection against hybrids”

Barton & Hewitt (1989) **Nature**

The genic concept of speciation



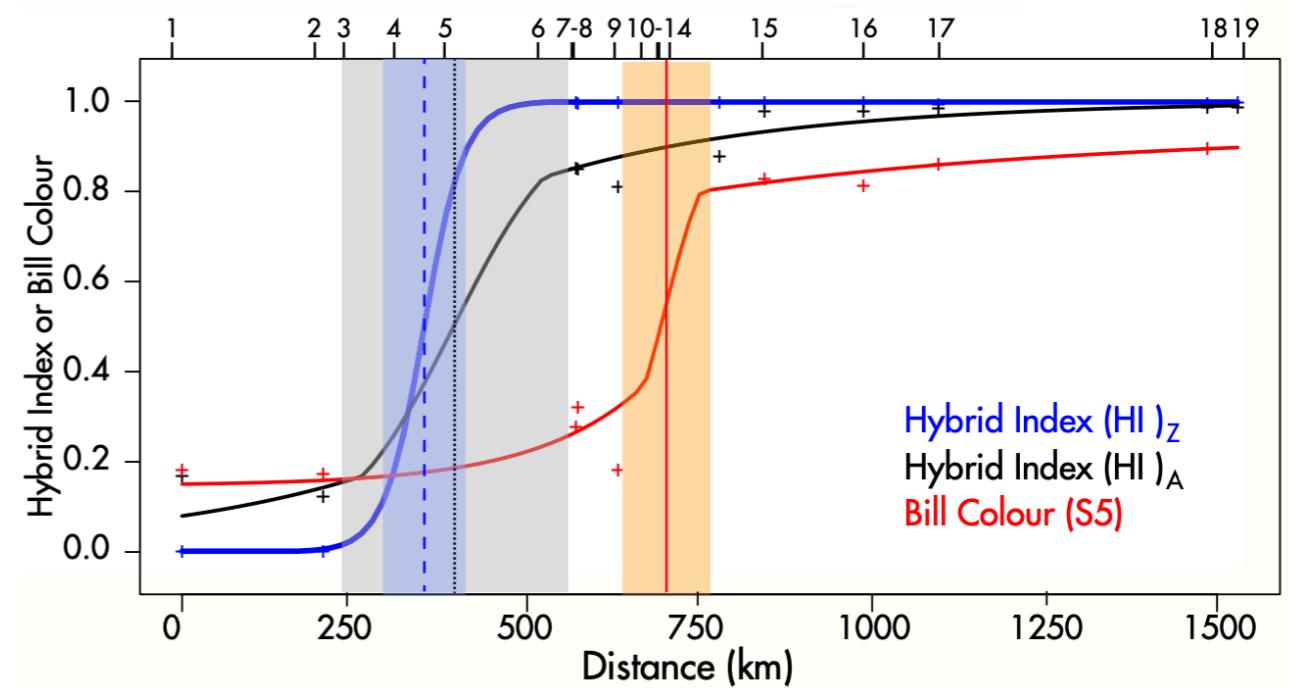
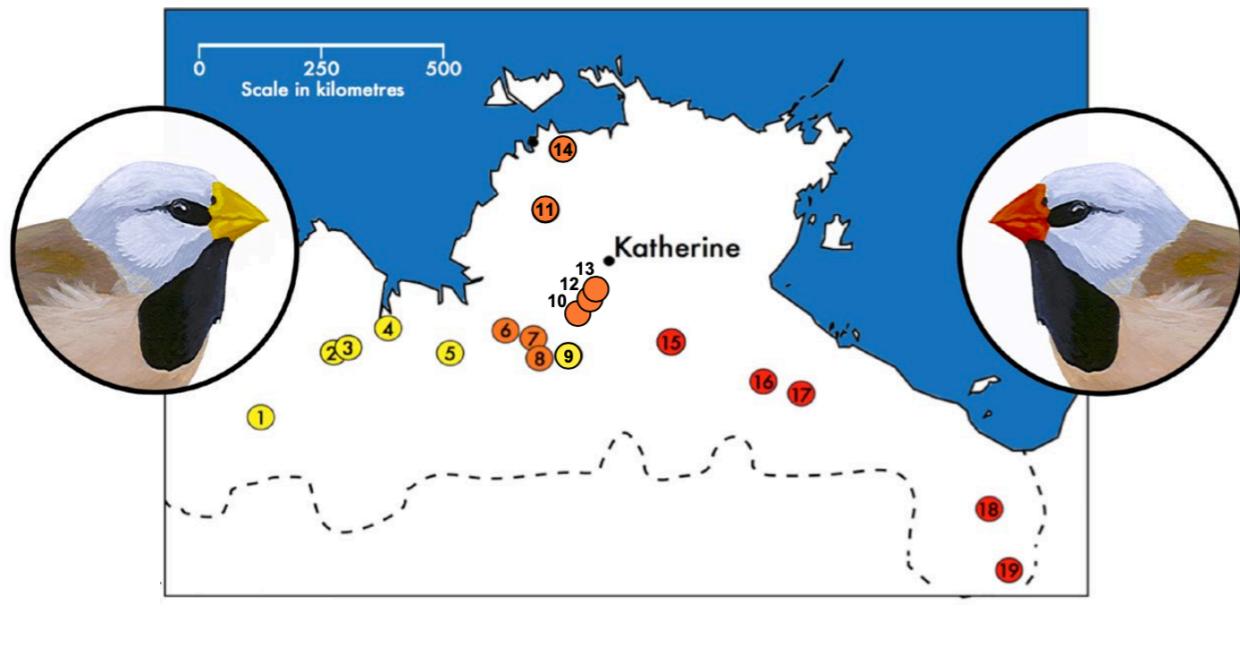
Divergent loci resist gene flow

Gene flow continues but
linkage builds and divergent
regions grow

Complete reproductive
isolation evolves

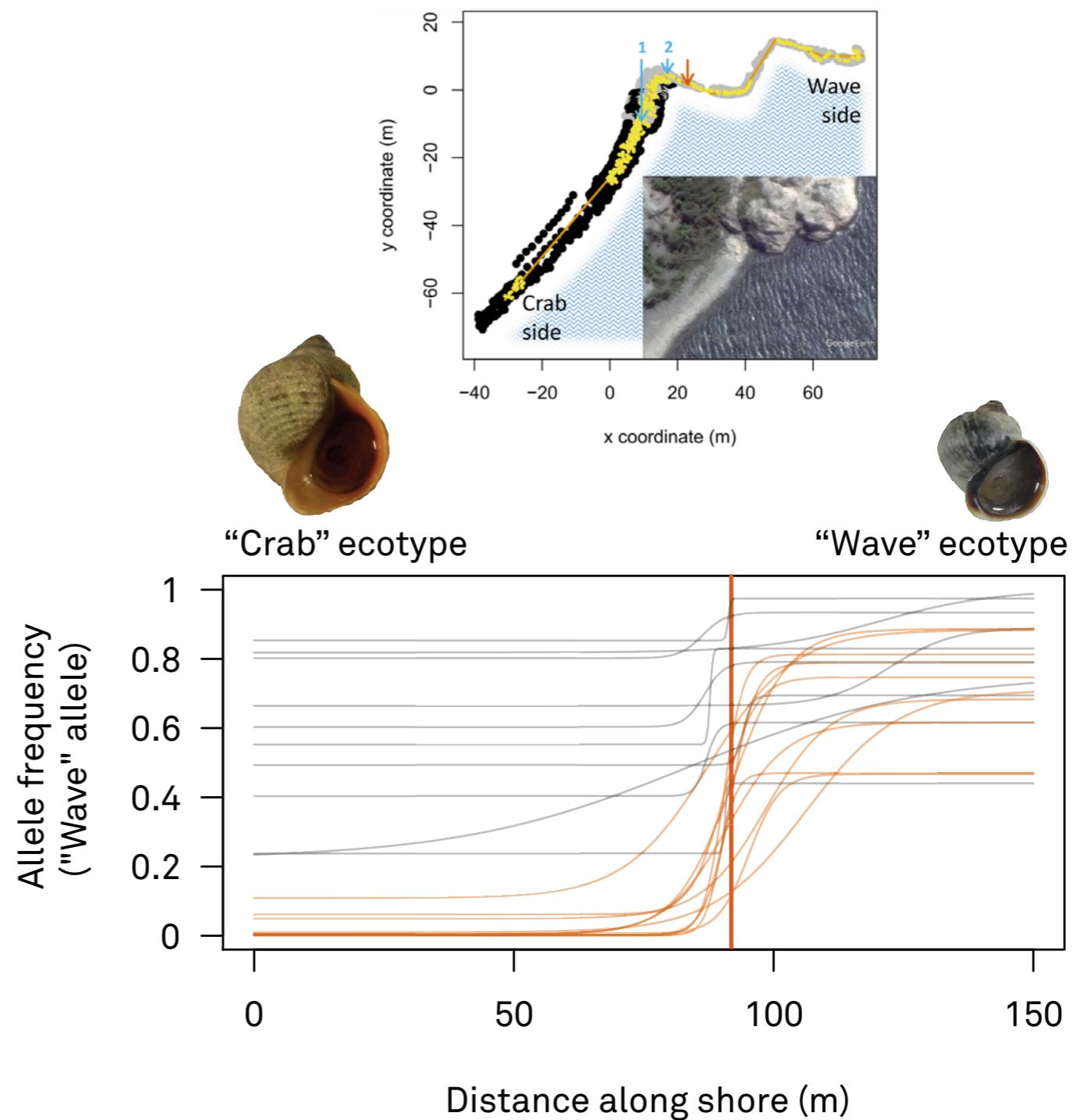
Hybrid zones: natural laboratories

- Contact zones between species
- Context on how some genes move across barriers



Hybrid zones: natural laboratories

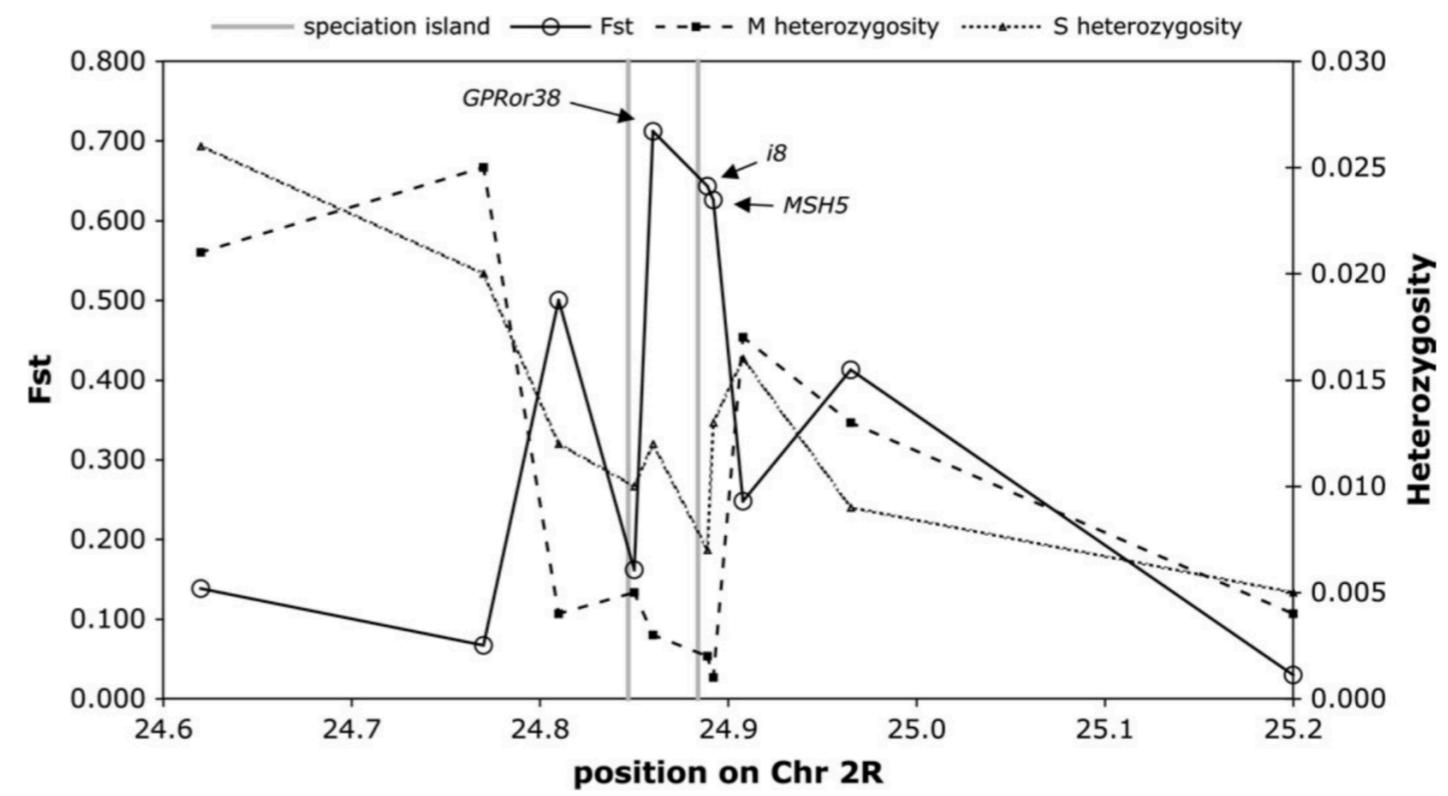
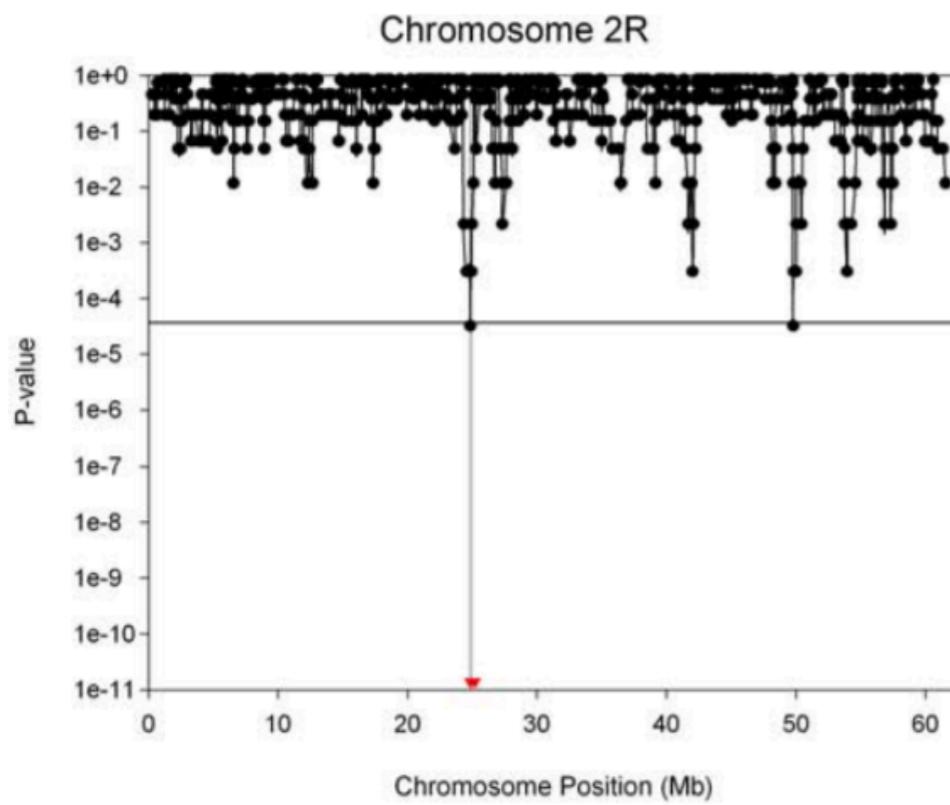
Littorina saxatilis
Western Sweden



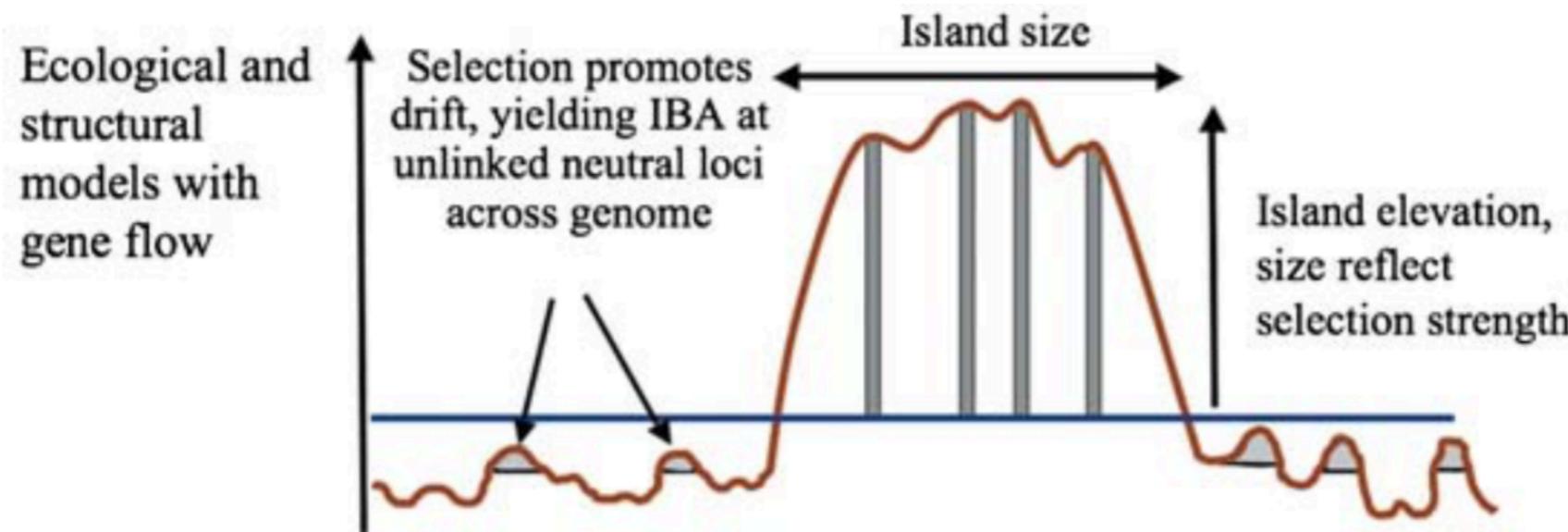
The rise of speciation islands



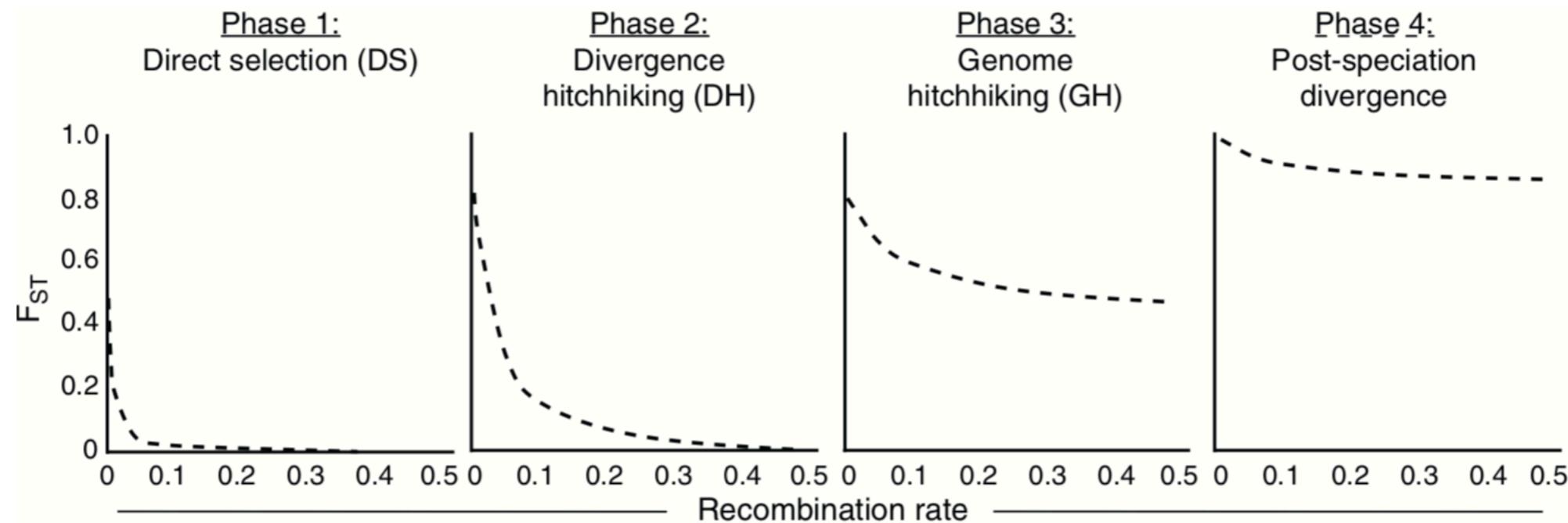
Anopheles gambiae
M + S forms



Speciation islands and processes

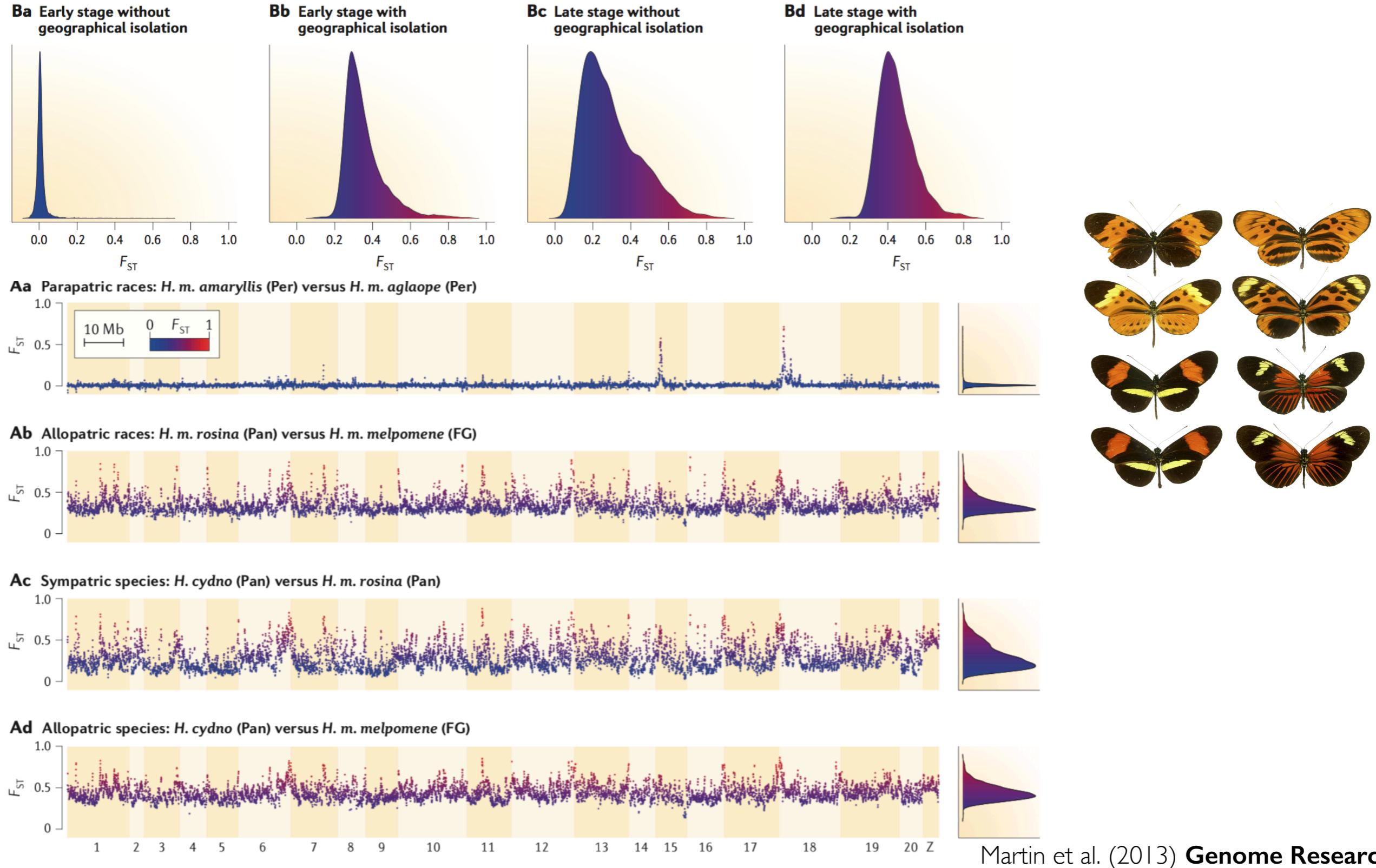


Nosil et al (2009) **Mol Ecol**

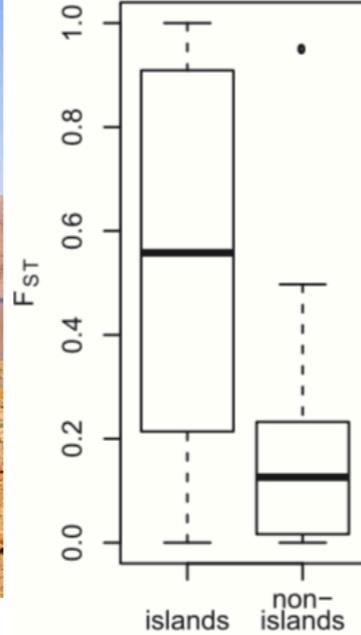


Feder et al (2012) **Trends in Genetics**

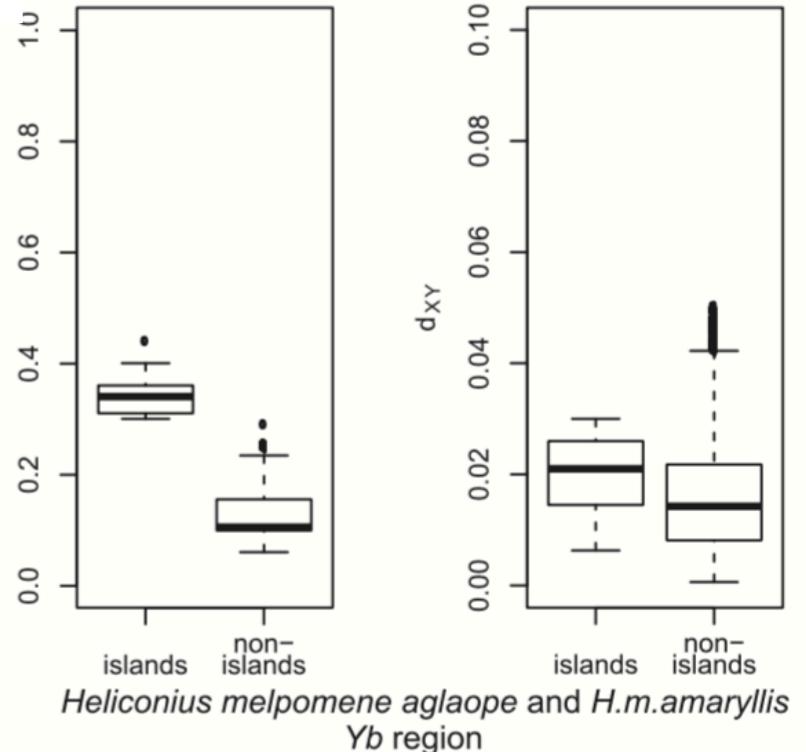
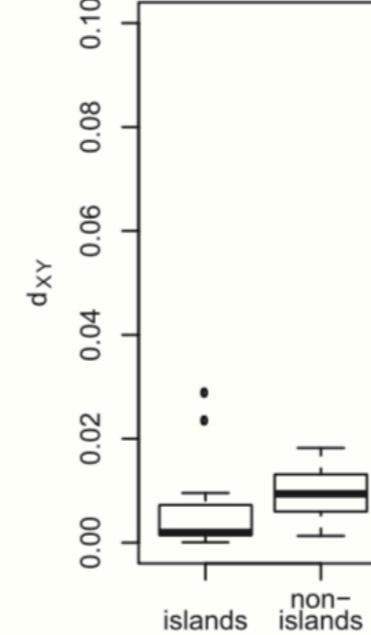
Continuums and islands



Mirages and alternative explanations



Anopheles coluzzii and *A. gambiae*

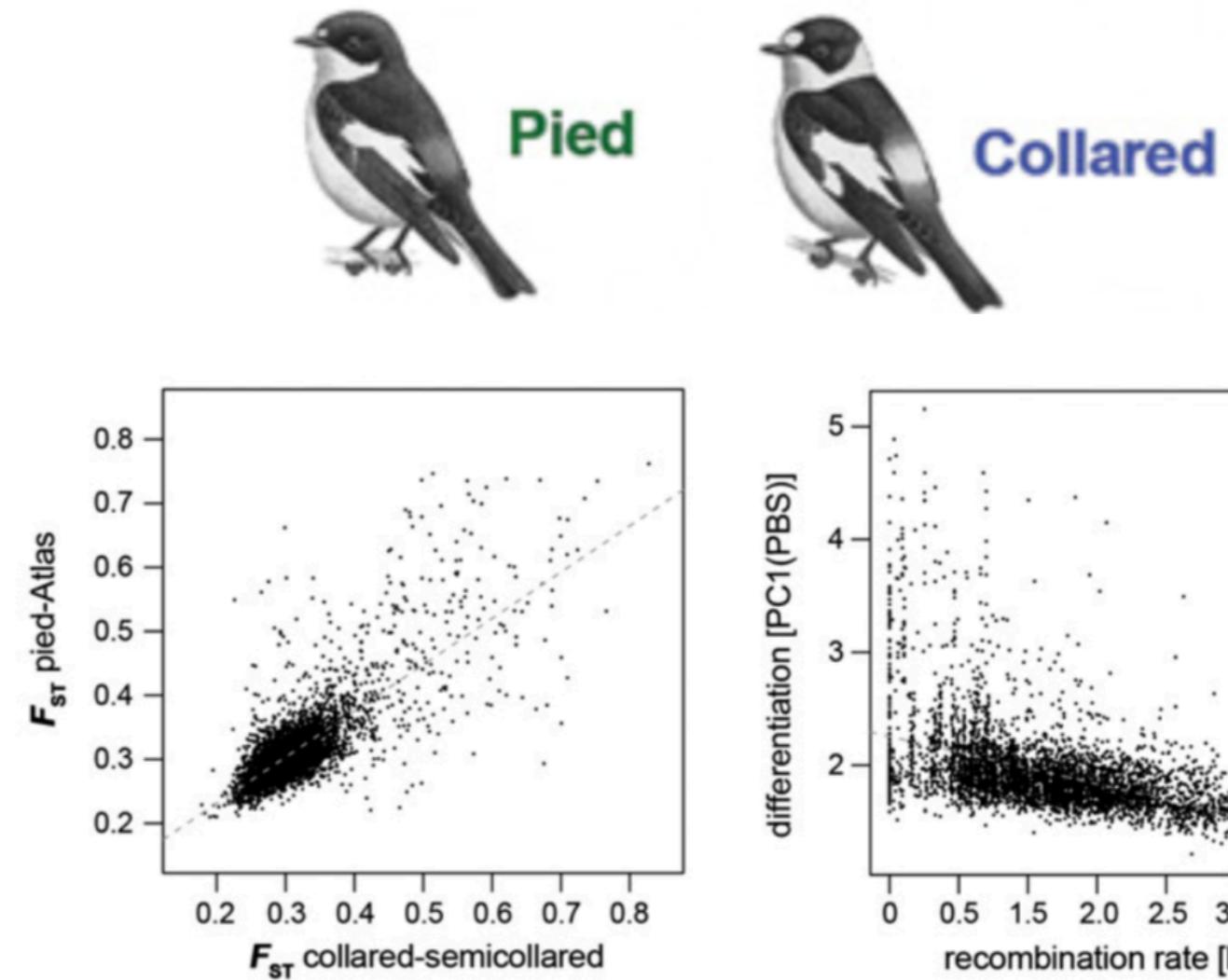
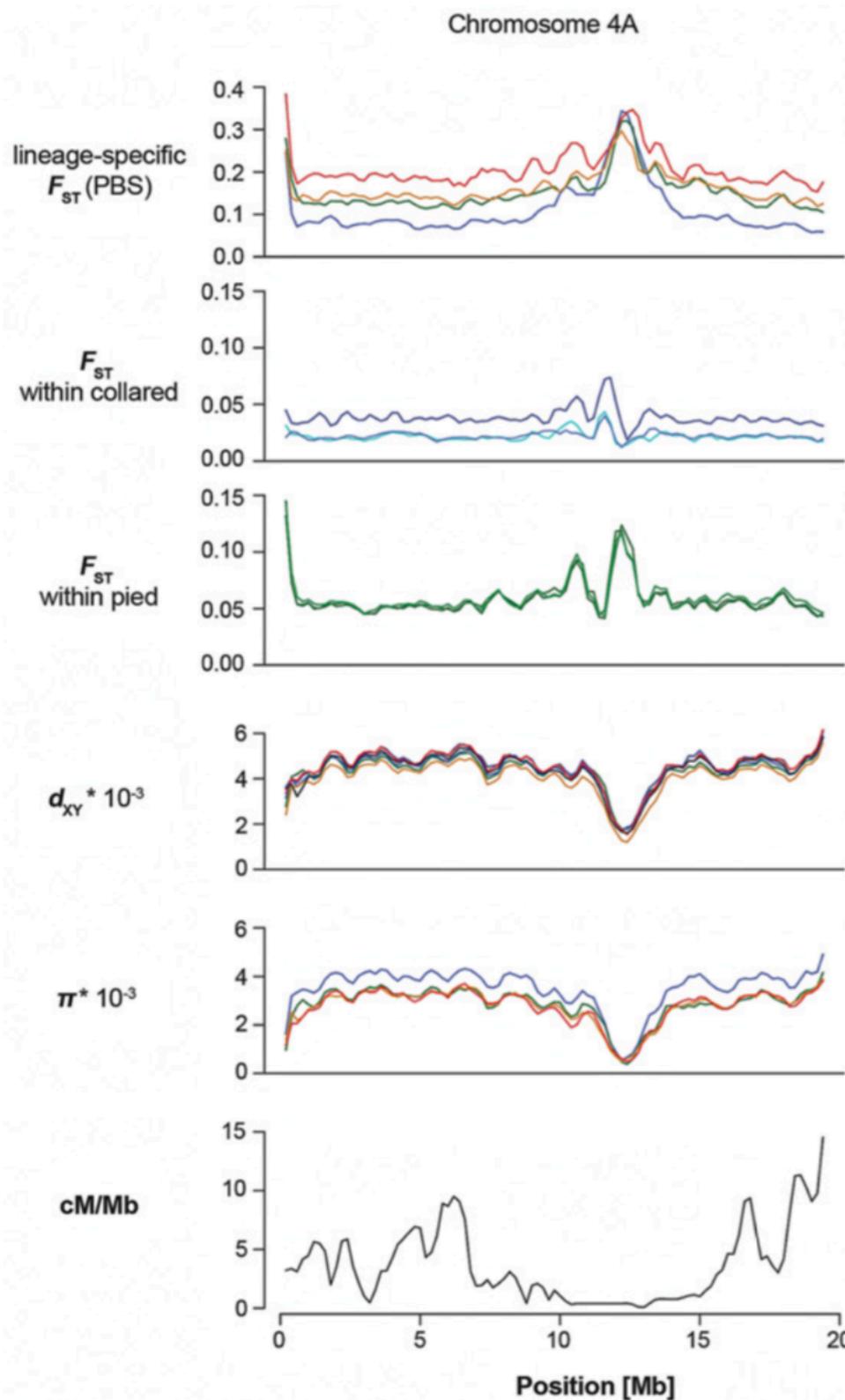


Heliconius melpomene aglaope and *H.m. amaryllis*
Yb region

- Background selection
- Local adaptation after isolation
- Shared ancestral polymorphism

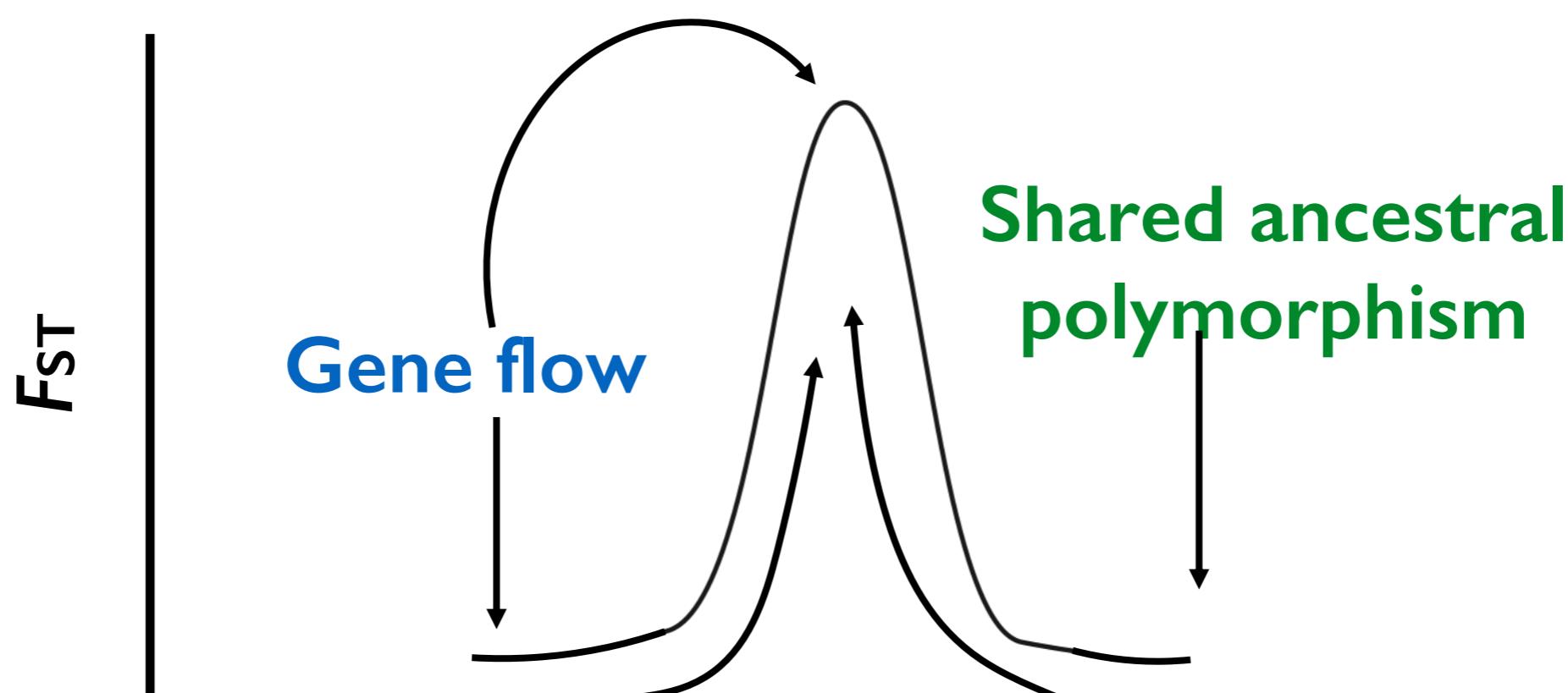
Noor & Bennett (2008) **Heredity**
Cruickshank & Hahn (2014) **Mol Ecol**

Linked selection and recombination



Confounding factors

Demographic history



Background selection

Shared ancestral polymorphism

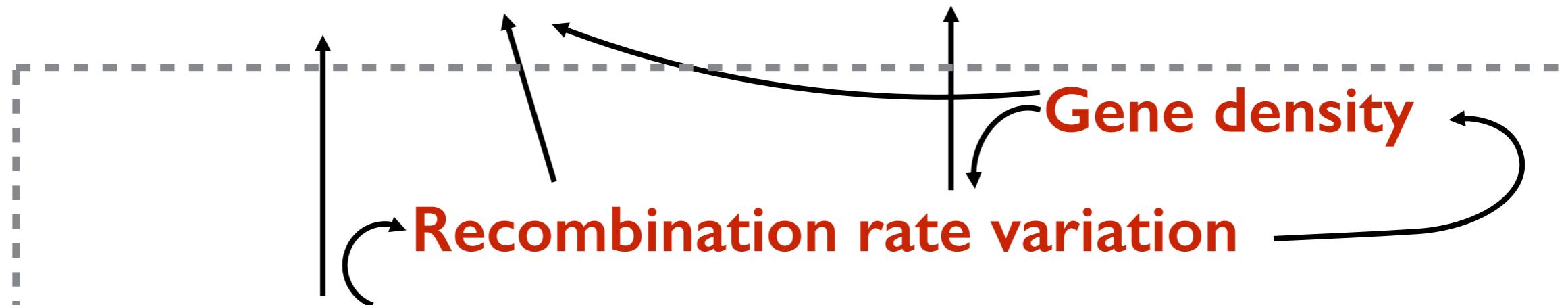
Divergent selection

Mutation rate variation

Genome features

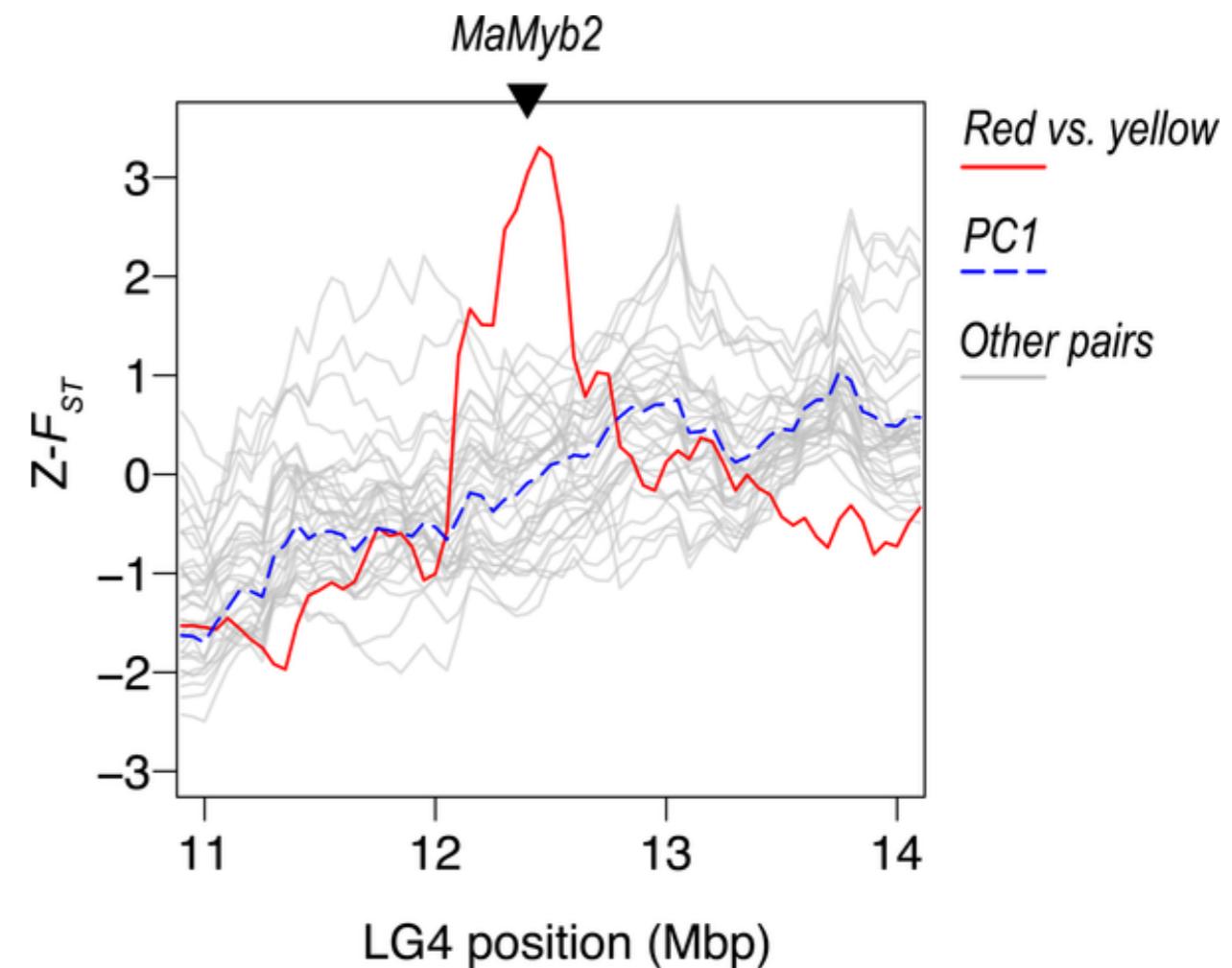
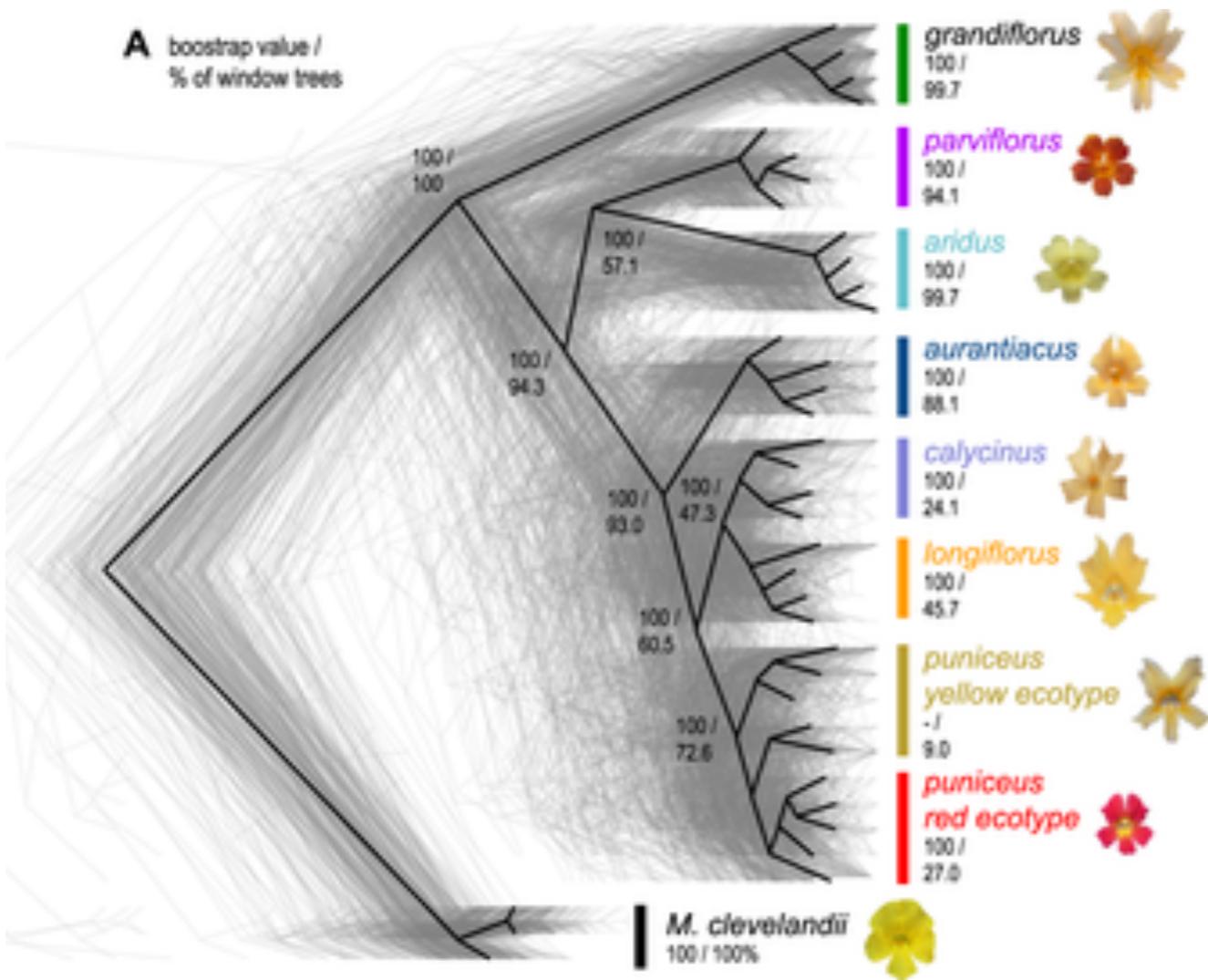
Recombination rate variation

Gene density

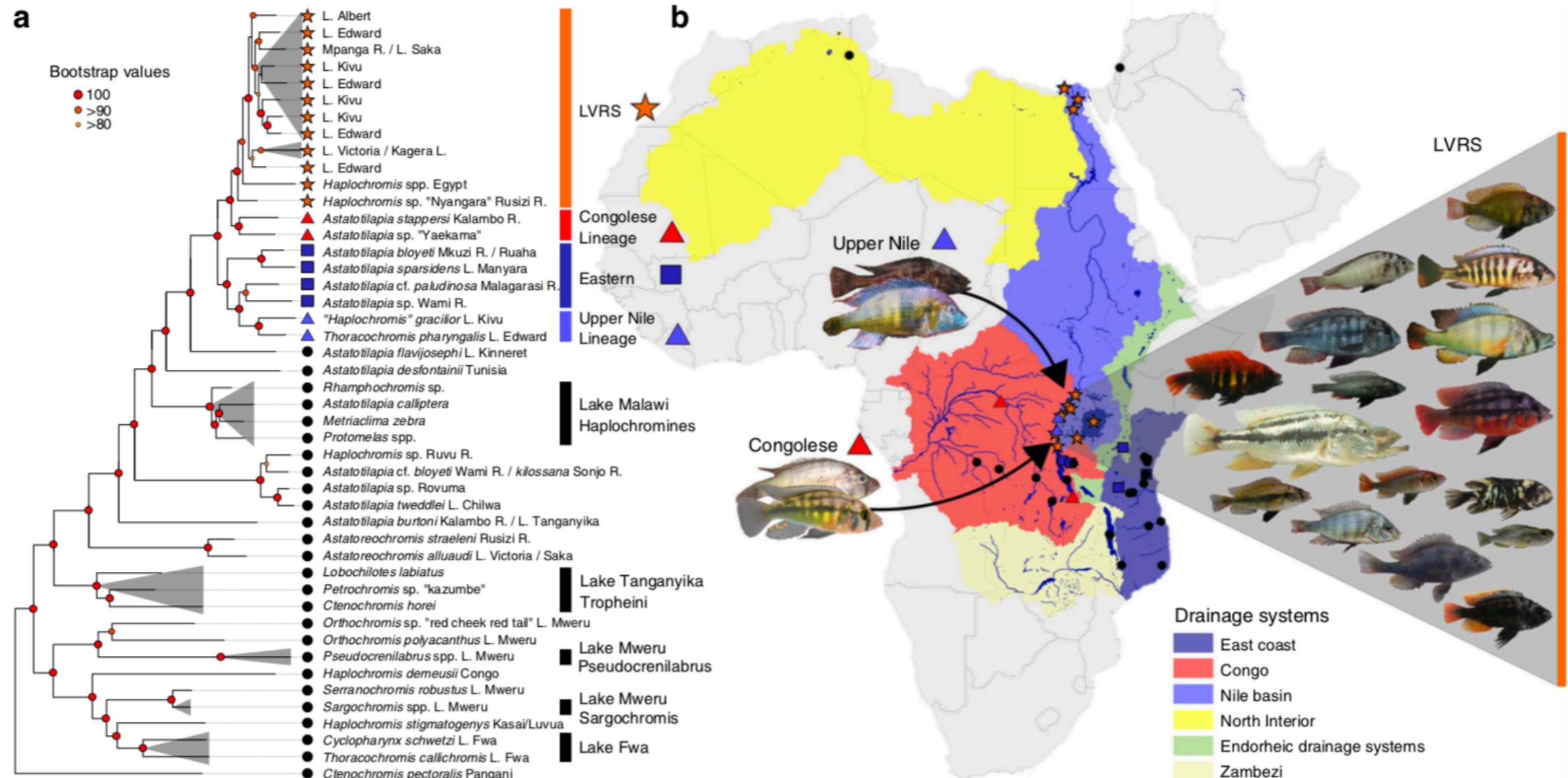


Evidence for speciation-with-gene-flow

- *Mimulus* monkeyflowers

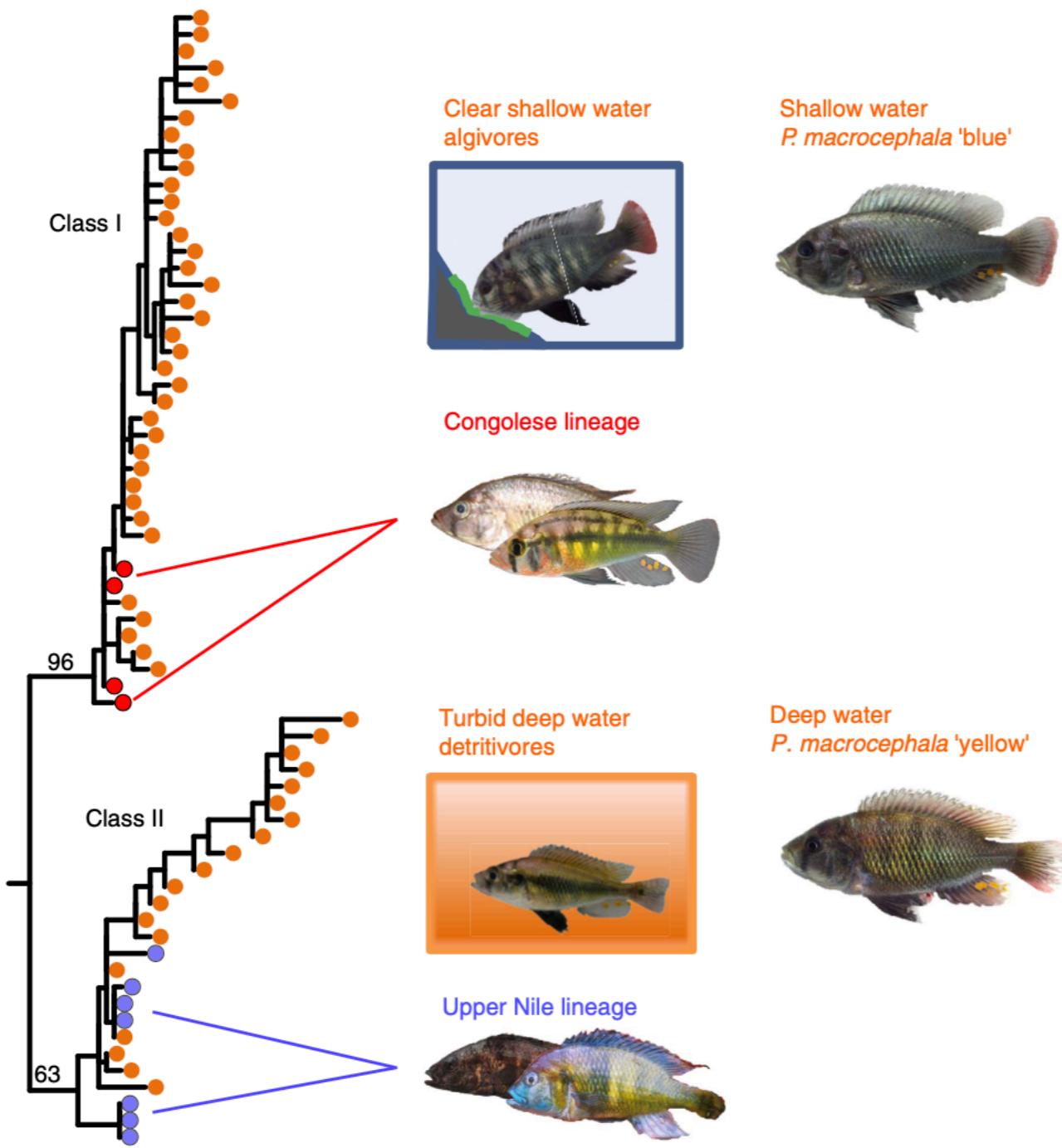


The Lake Victoria cichlid radiation



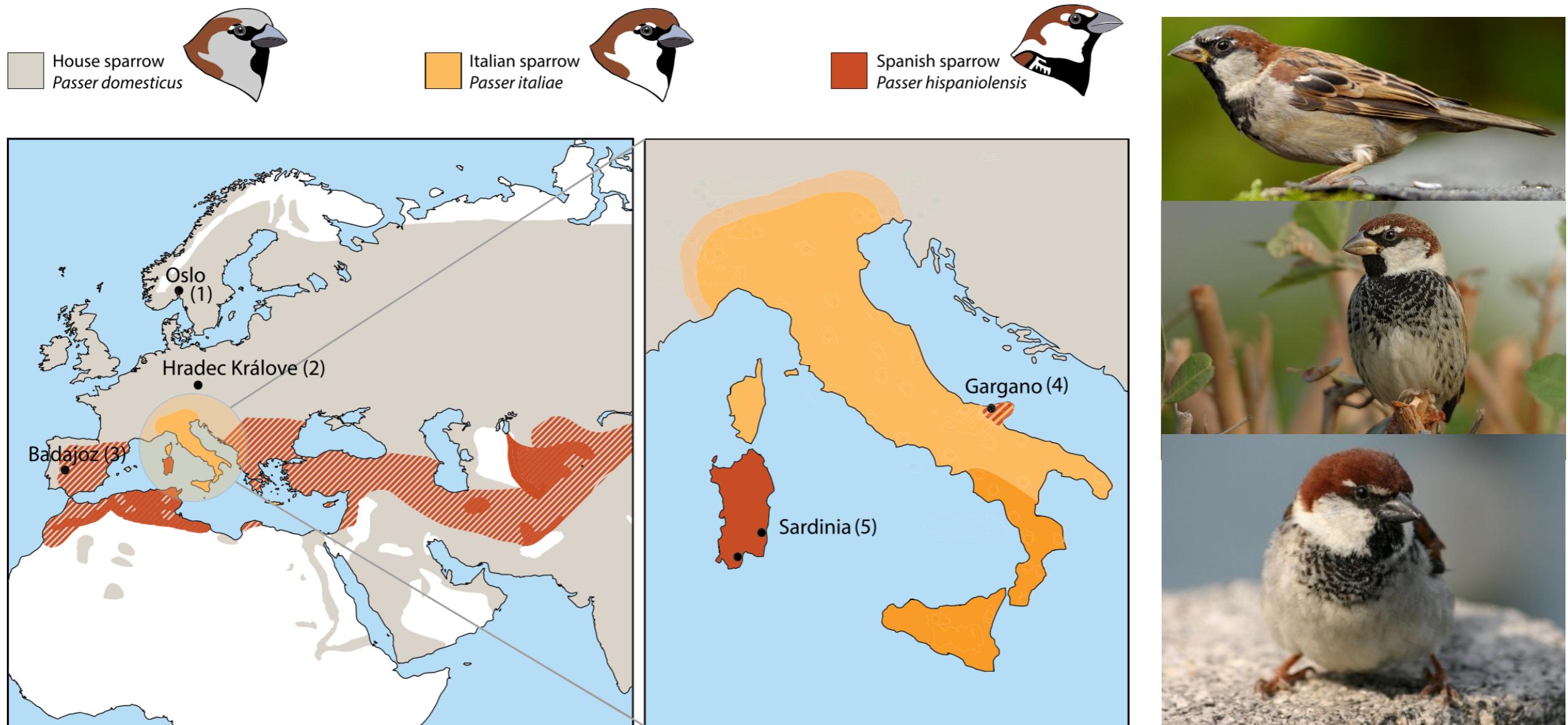
The importance of hybridization

- Opsin genes in Lake Victoria fish

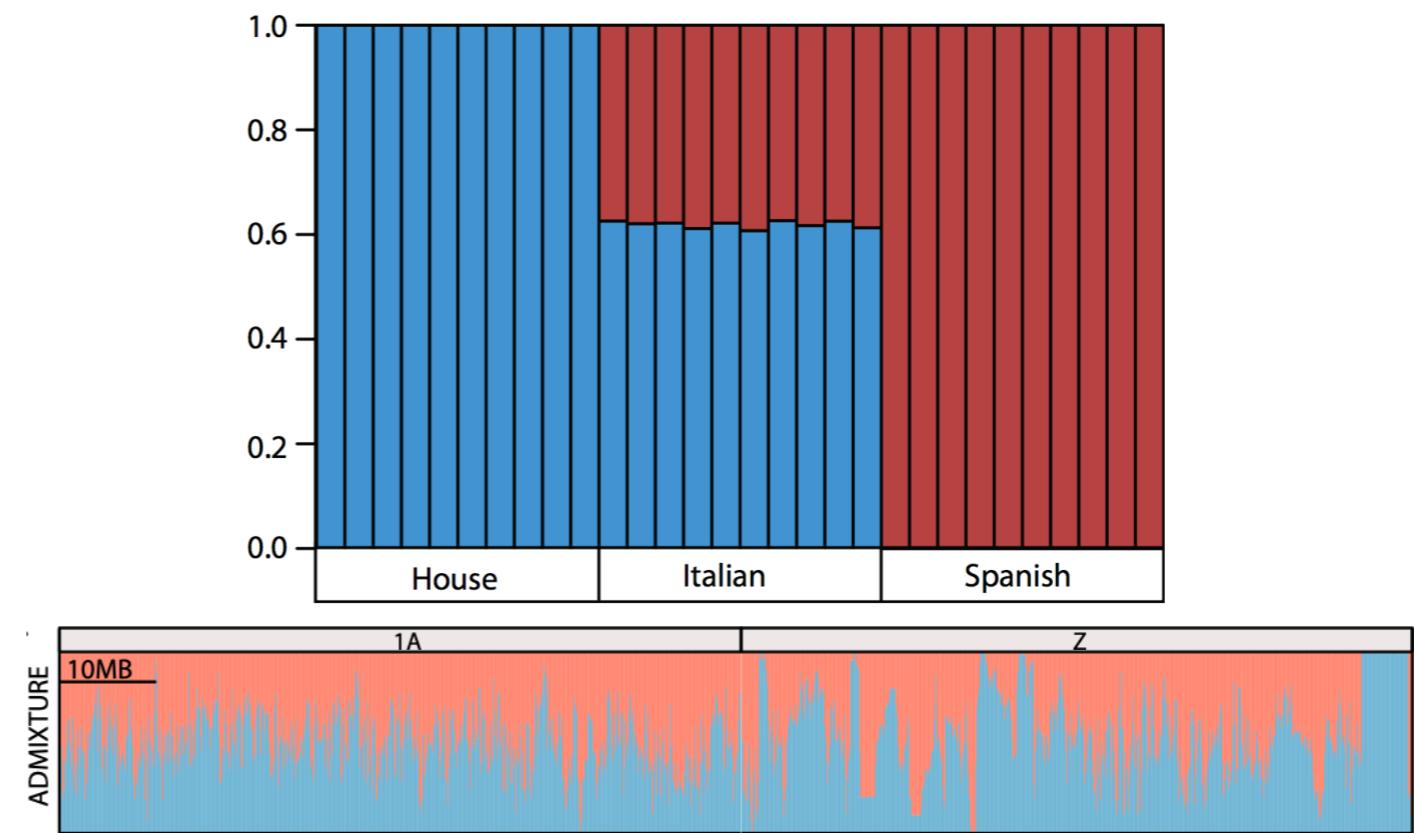
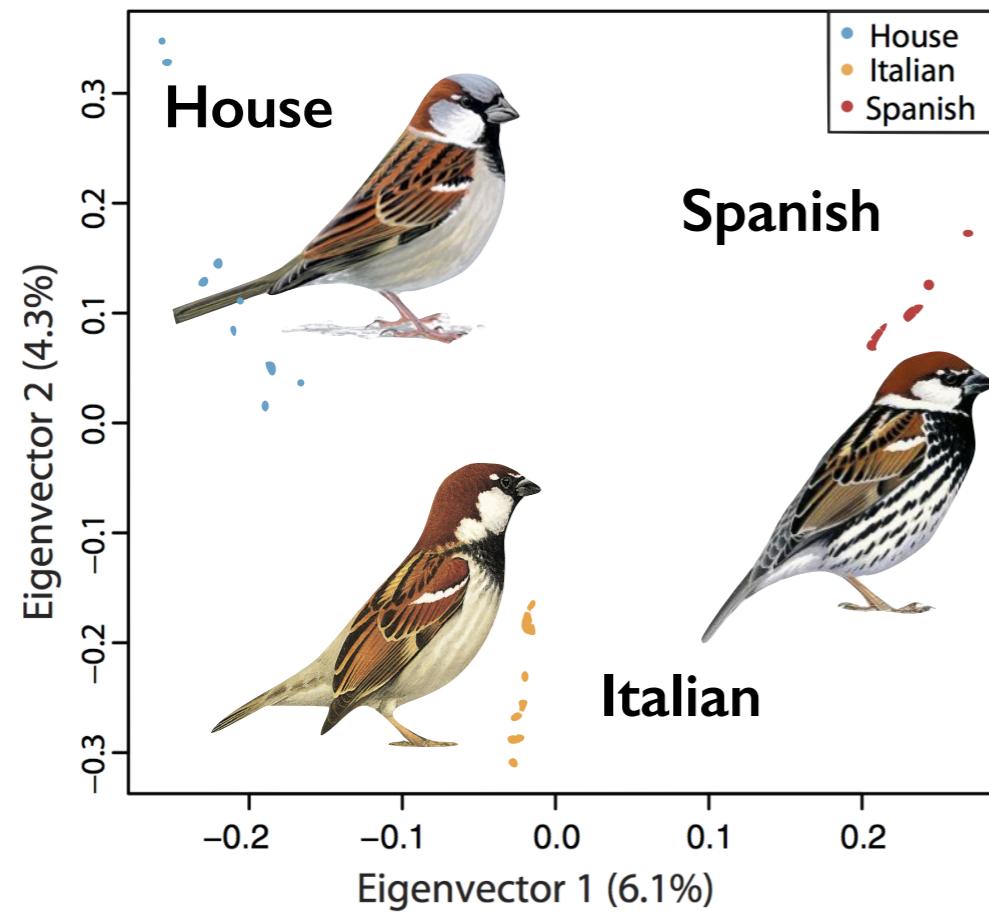


Hybridization and speciation

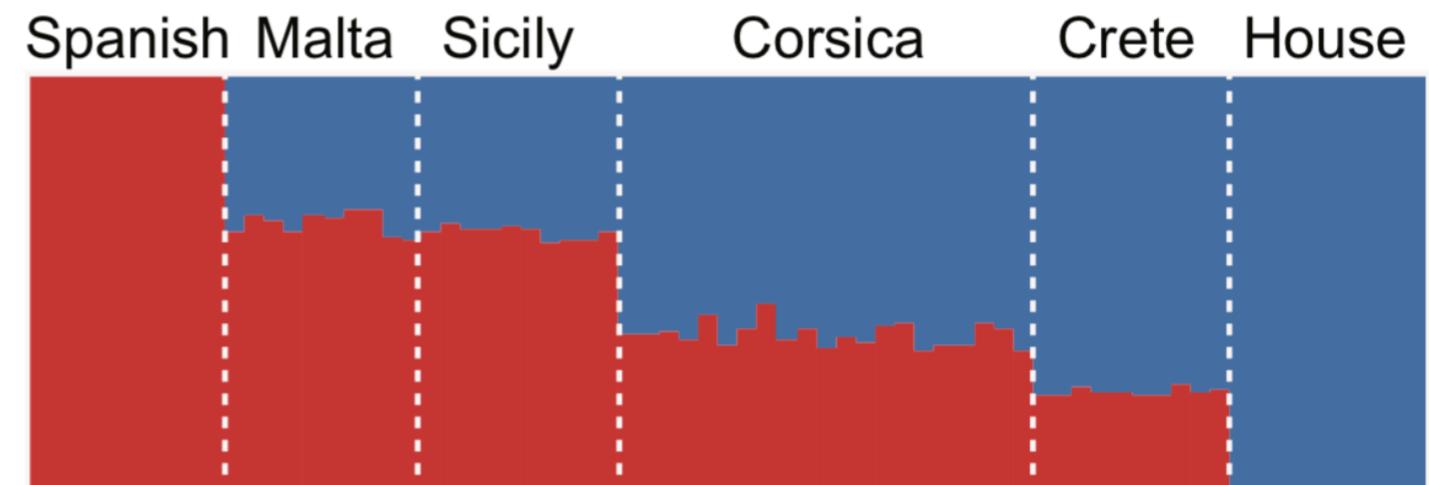
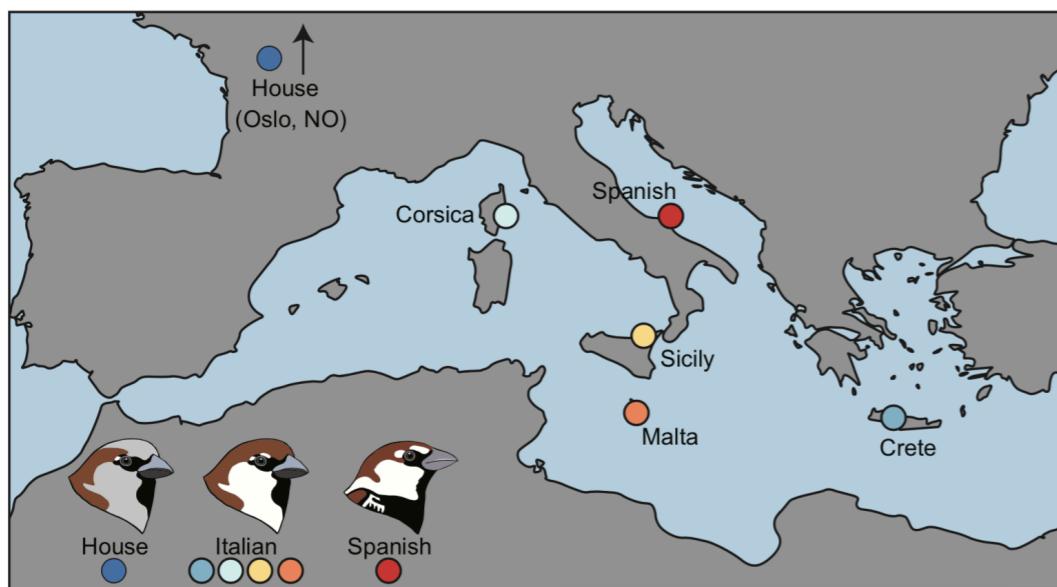
- Creative power of gene flow – resulting in new species



Hybridization and speciation

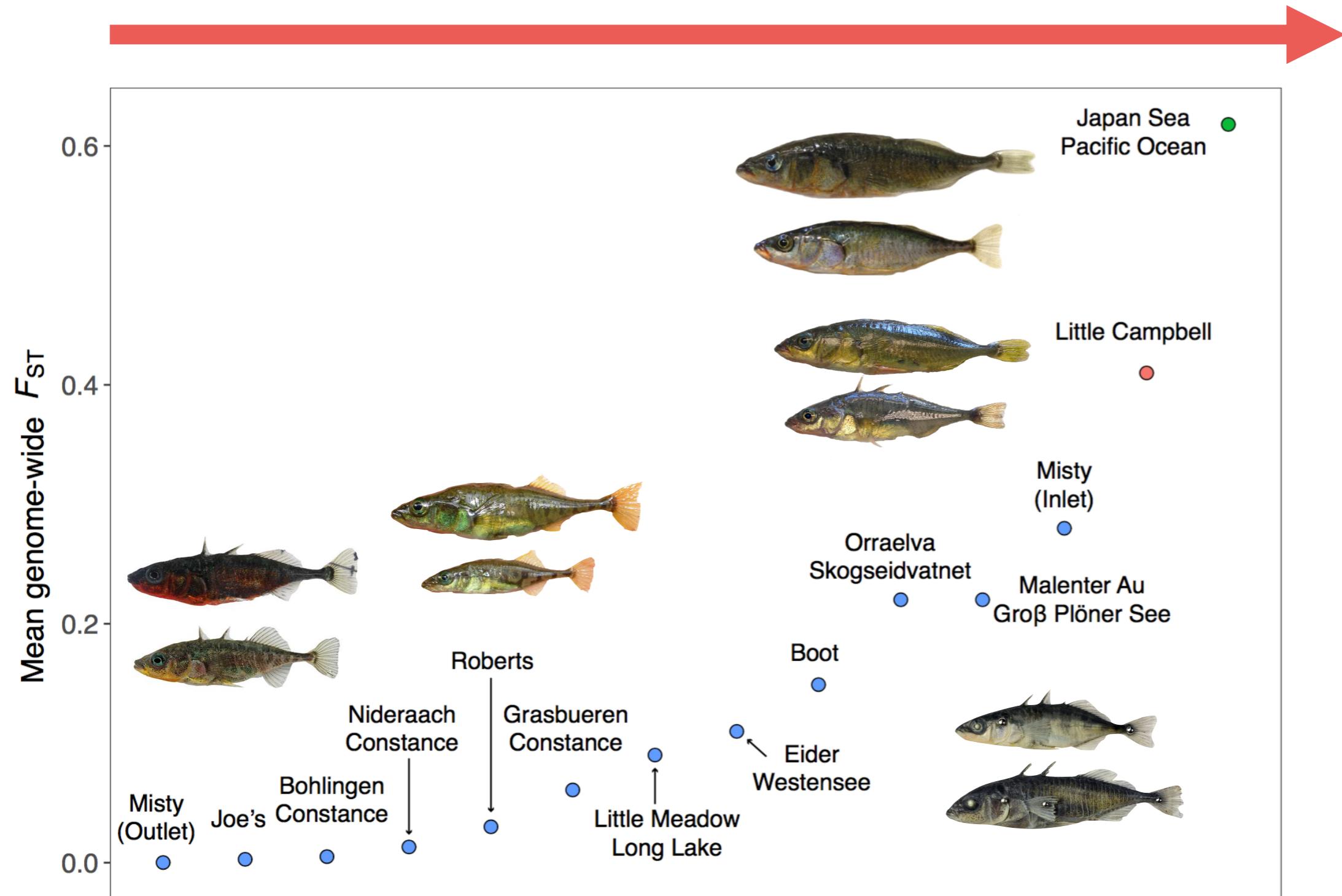


Elgvin et al (2017) Science Advances



Runemark et al (2018) Nat Ecol Evol

The stickleback speciation continuum



Roesti et al (2012) **Mol Ecol**

Roesti et al (2015) **Nat Comm**

Ravinet et al (2018) **PloS Genetics**

Rank order

● Anadromous-stream ● Japanese ● Lake-stream

Feulner et al (2015) **PloS Genetics**

Kusukabe et al (2017) **Mol Ecol**

Marques et al (2016) **PloS Genetics**

Late stage speciation in sticklebacks



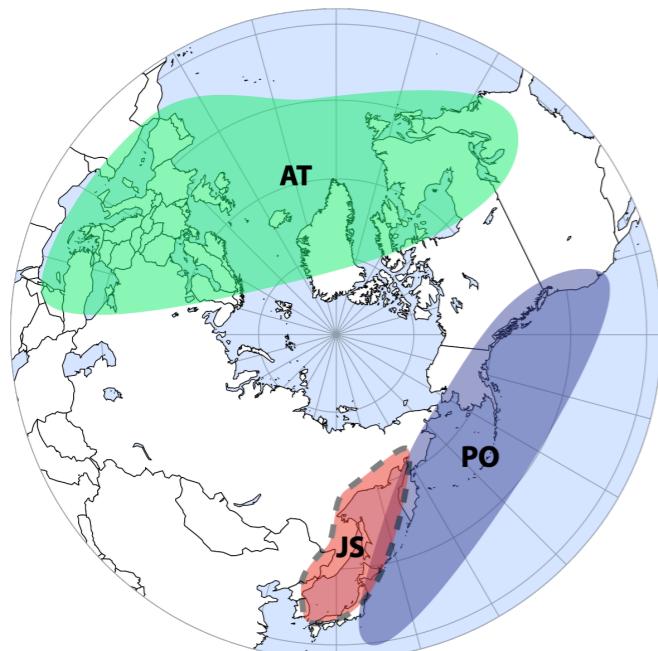
Three-spined stickleback

Pacific Ocean Atlantic Ocean



Japan Sea stickleback

Sea of Japan Sea of Okhotsk



Early Pleistocene



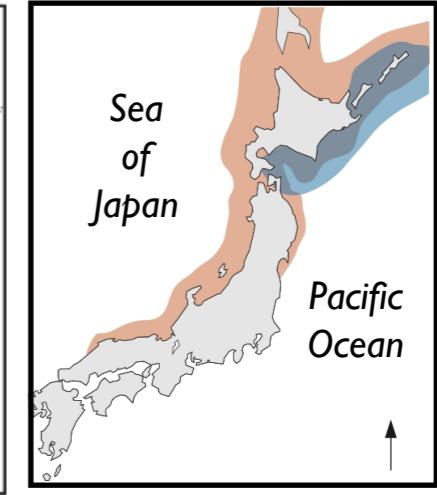
1 - 3 Myr BP

Last glacial

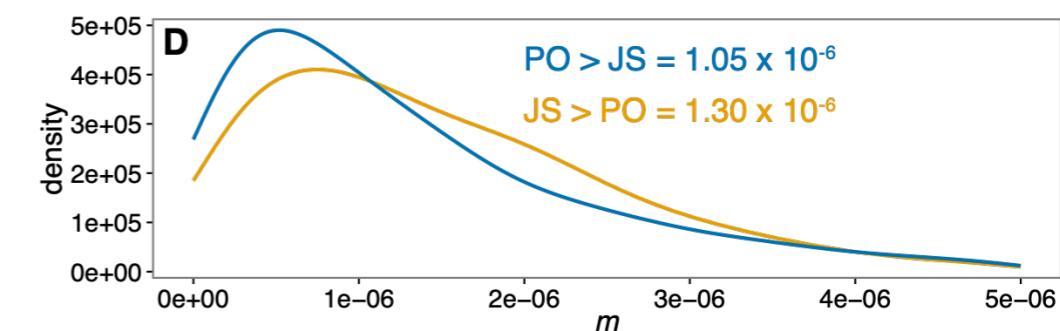
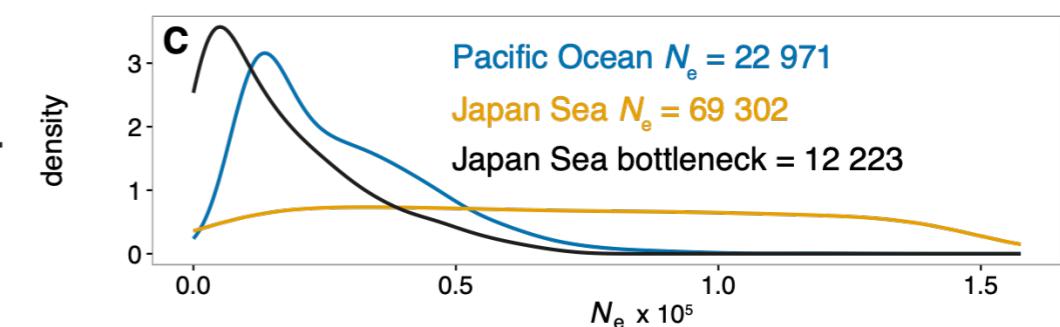
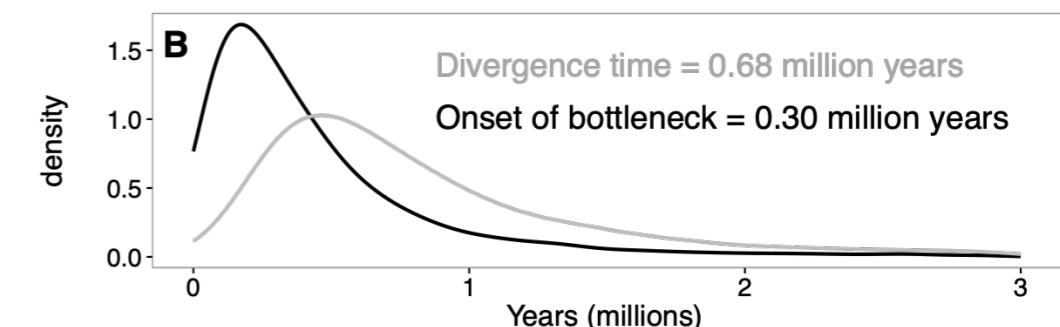
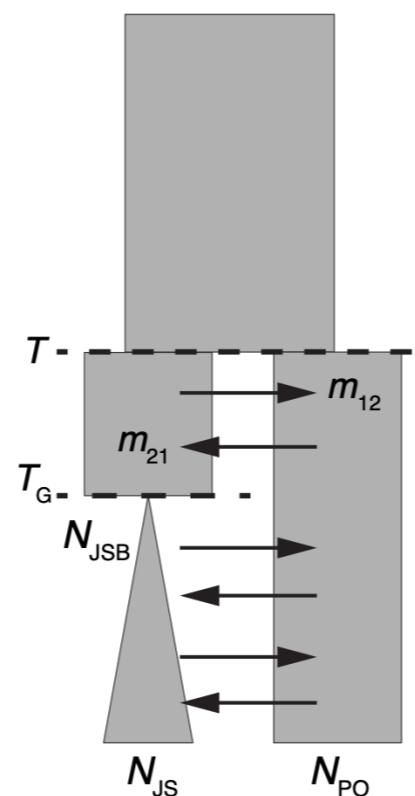


10 - 70 Kyr BP

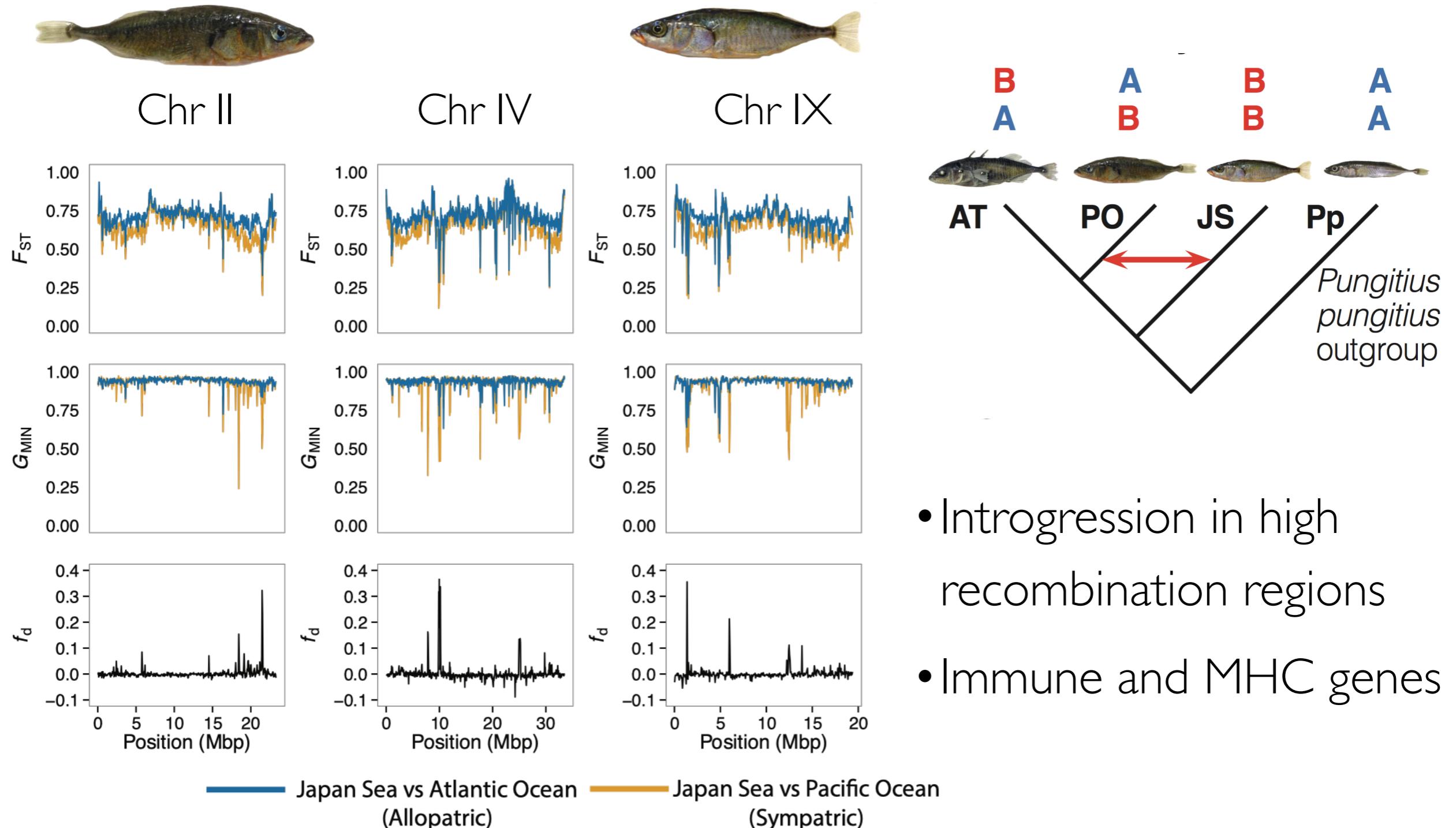
Present day



A Constant migration + bottleneck

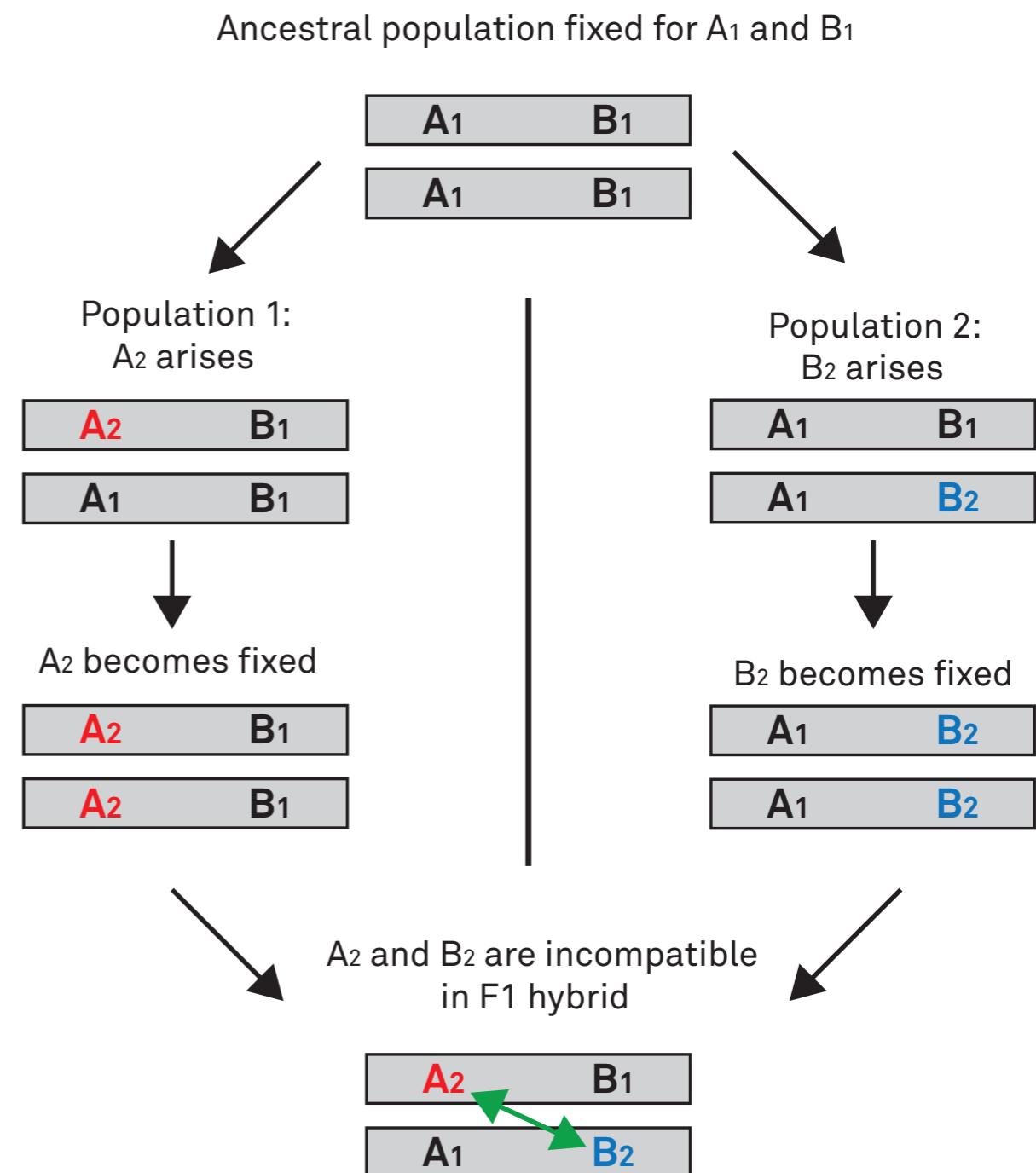


Introgression localised in the genome



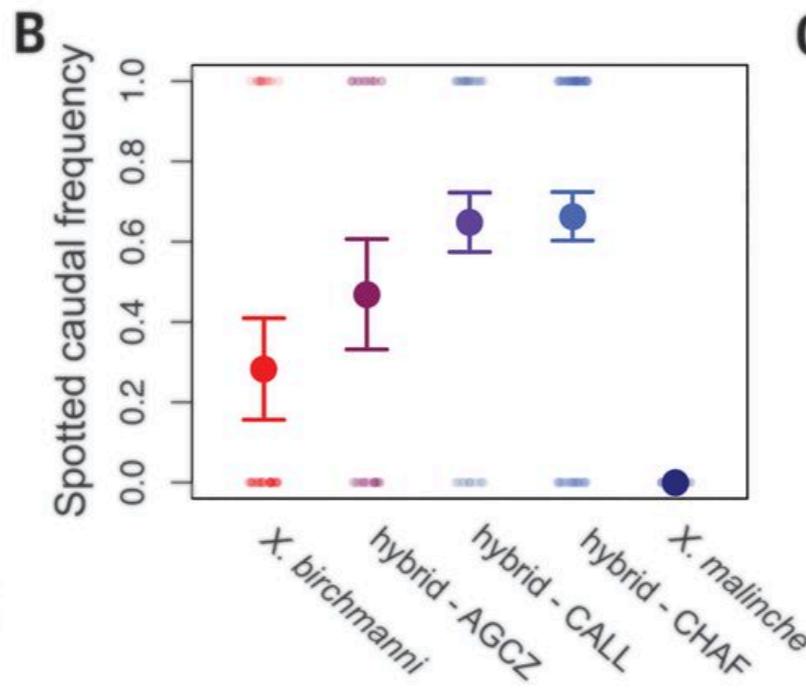
Genetic basis of reproductive isolation

- DMI – Dobzhansky-Mueller Incompatibilities
- Limited understanding of genetic basis
- ~12 genes identified across different species
- Mainly model species

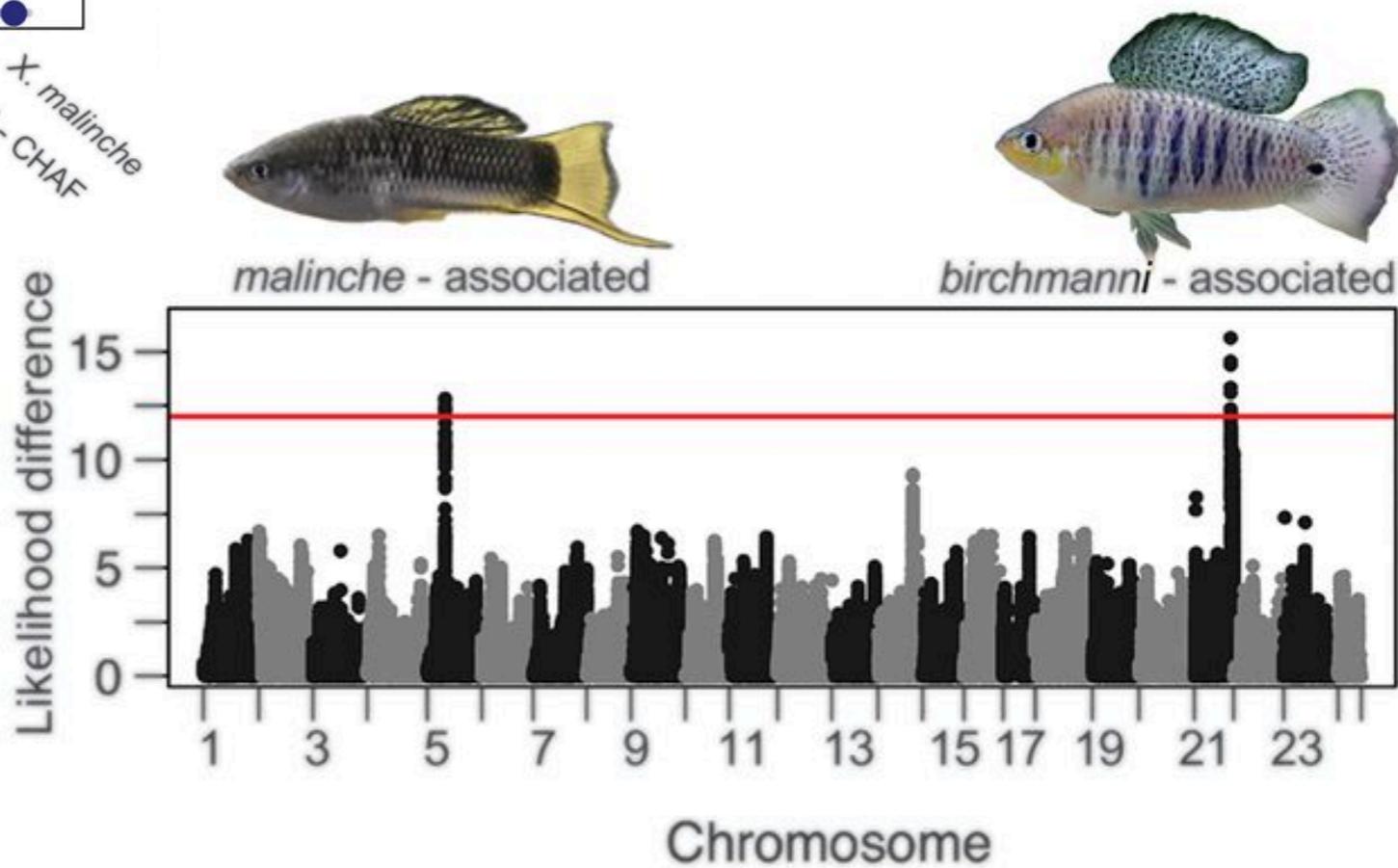


Genetic basis of reproductive isolation

- *Xiphophorus* swordtails – caudal melanoma

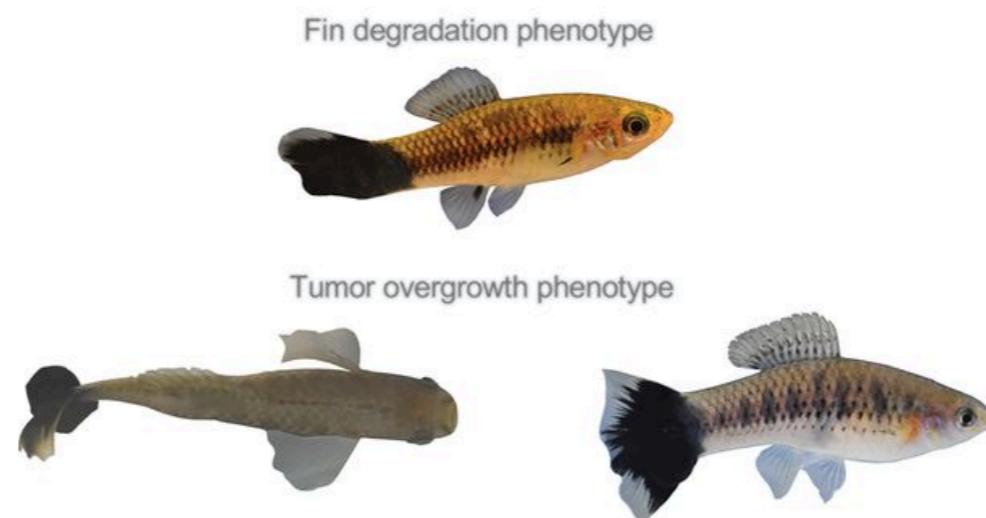


C

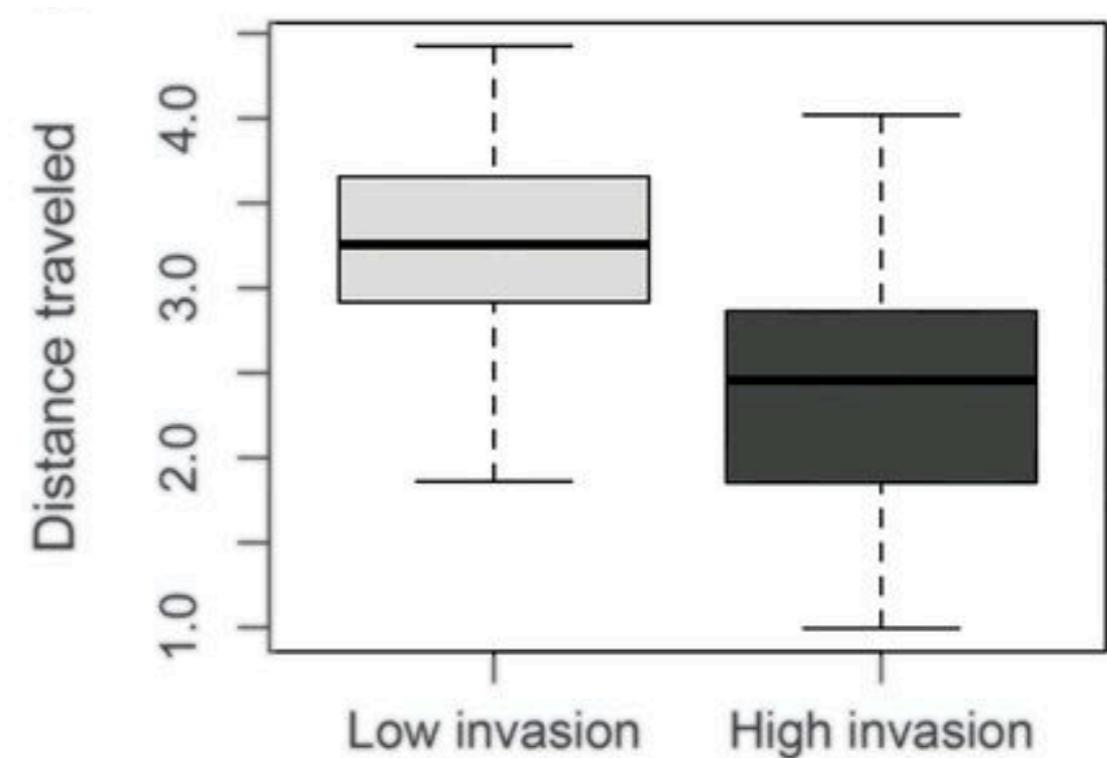
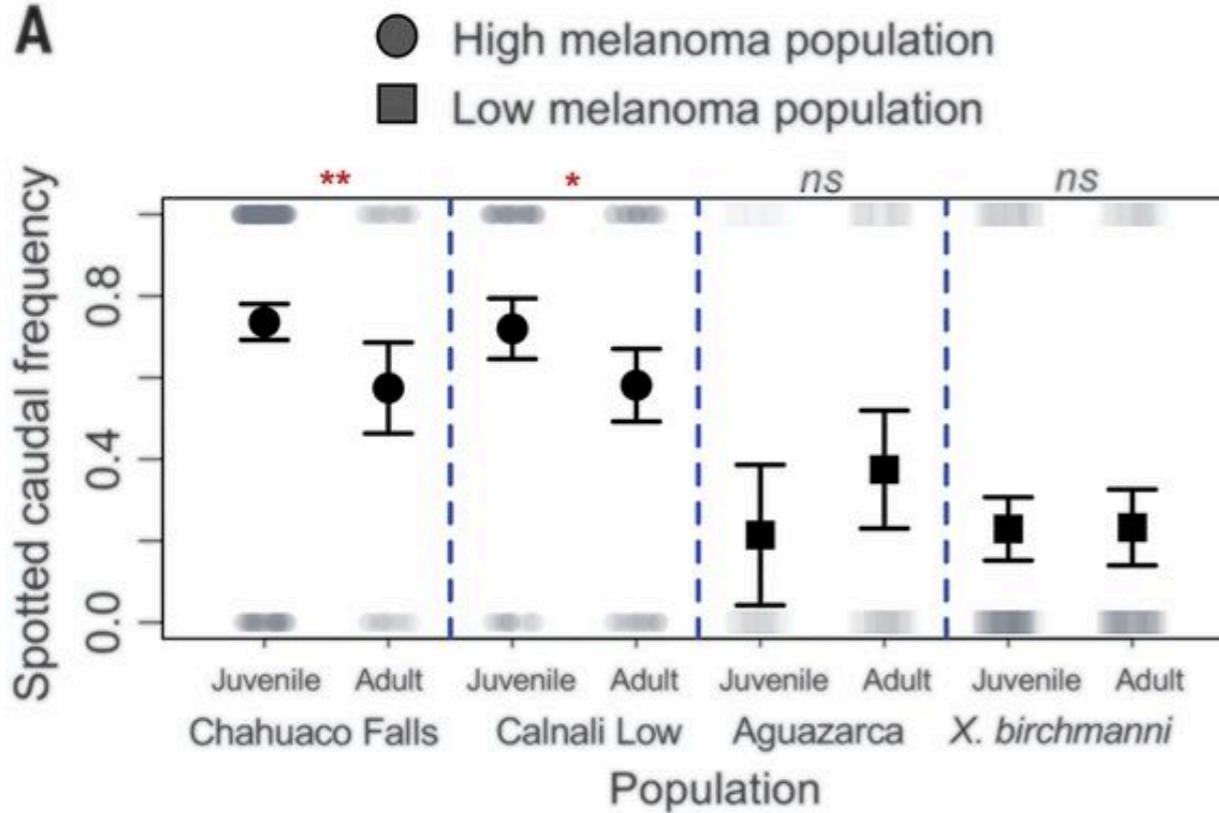


Powell et al (2020) Science

Genetic basis of reproductive isolation



A





A confusing field - what is the way forward?



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ScienceDirect

Current Opinion in
Genetics
& Development

Interpreting the genomic landscape of introgression

Simon H Martin and Chris D Jiggins



M. RAVINET*† R. FARIA‡§¶, R. K. BUTLIN¶**, J. GALINDO††, N. BIEF
M. RAFAJLOVIĆ§§ M. A. F. NOOR¶¶ B. MEHLIG§§ & A. M. WESTR

COMMENTARY

**Parallelism in genomic
landscapes of differentiation,
conserved genomic features
and the role of linked selection**

EVIEWS

RESPONSE

**Land ahoy? Navigating the
genomic landscape of
speciation while avoiding
shipwreck**

A. M. WESTRAM* & M. RAVINET†

H. ELLEGREN

Making
different



Open Access

Jochen B. W. Wolf¹



Interpreting differentiation landscapes
in

What is Speciation Genomics? The roles of ecology, gene
flow, and genomic architecture in the formation of species

Reto¹

C. RYAN CAMPBELL, J. W. POELSTRA and ANNE D. YODER*

What we hope to achieve

- Clarify an increasingly complex and difficult field
- Teach you the tools and approaches necessary to go from raw sequencing reads to finished analyses
- Teach best practices - learn from our mistakes!
- Generate discussion and interaction
- Create a resource you can refer back to throughout your analyses and research

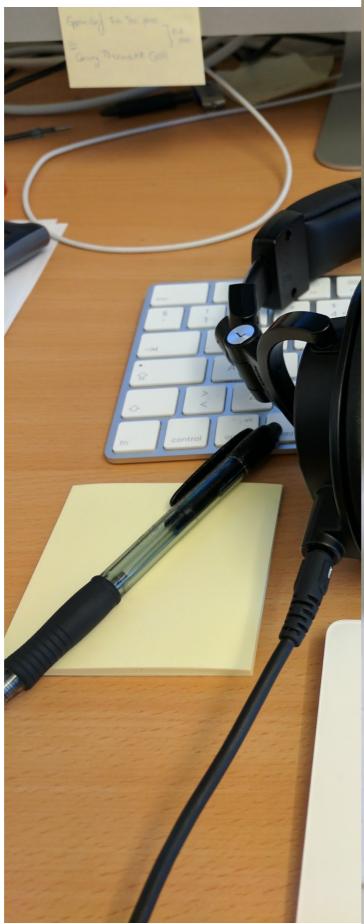
speciationgenomics.github.io

What we hope to achieve

1. Learning how to use Unix
2. Handling NGS data - mapping reads, variant calling & filtering
3. Investigating population structure
4. Detecting and testing for hybridisation
5. Demographic inference
6. Genome scans and identifying signatures of selection

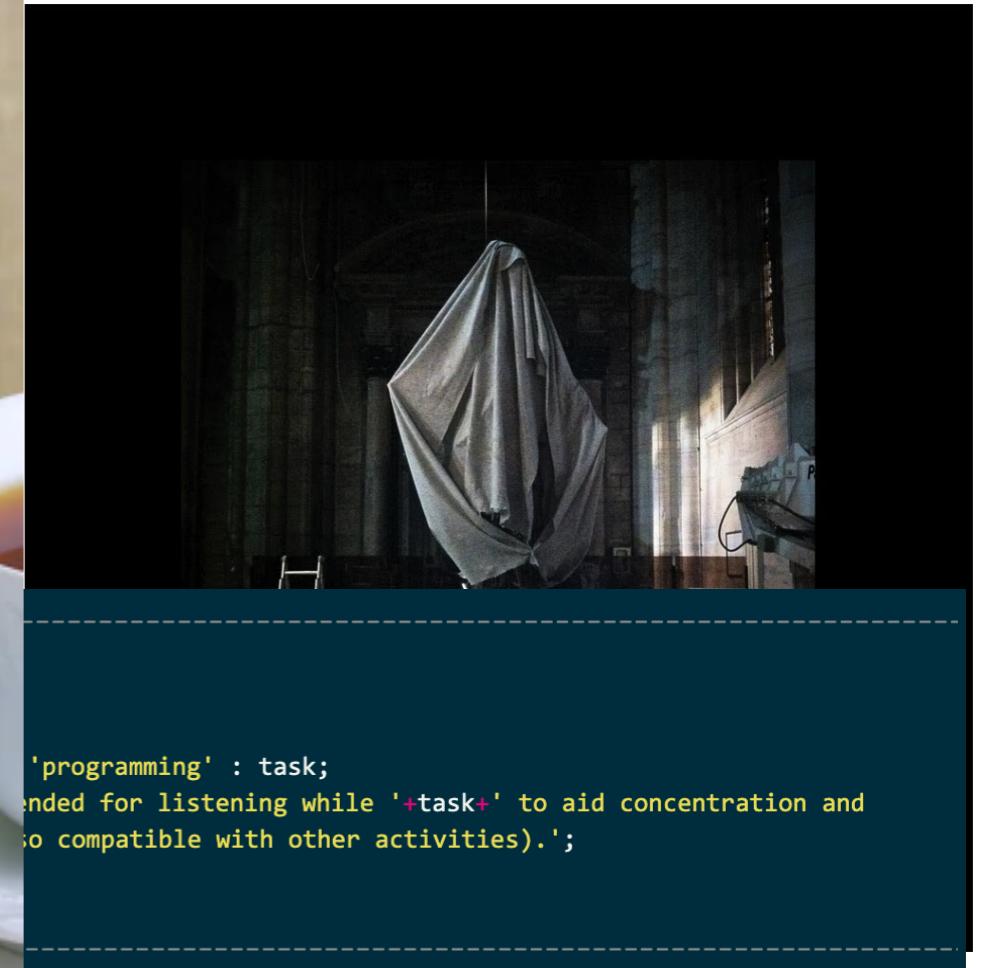
speciationgenomics.github.io

Bioinformatics secret weapons



Google

Please help me with my bioinformatics problems



```
'programming' : task;  
    intended for listening while '+task+' to aid concentration and  
    so compatible with other activities).';
```

Bioinformatics secret weapons



Some new online additions

Padlet for anonymous questions/discussions and issues

<https://padlet.com/markravinet/ljz8n25uftrx130t>

Online code sharing

<https://codeshare.io/GAAZYx>

Polls