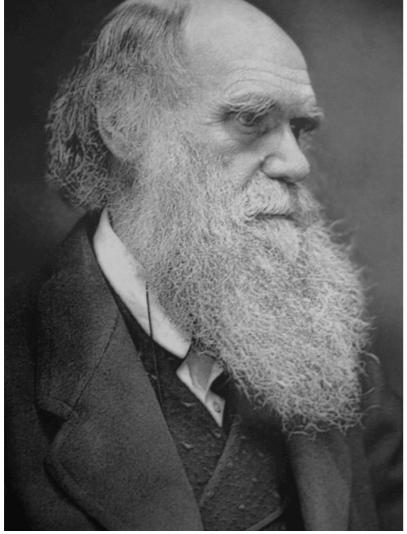


# Concepts, islands & continuums: a perspective on speciation genomics



Mark Ravinet  
Centre for Ecological and Evolutionary Synthesis  
University of Oslo, Norway  
[@mark\\_ravinet.mark.ravinet@ibv.uio.no](mailto:@mark_ravinet.mark.ravinet@ibv.uio.no)

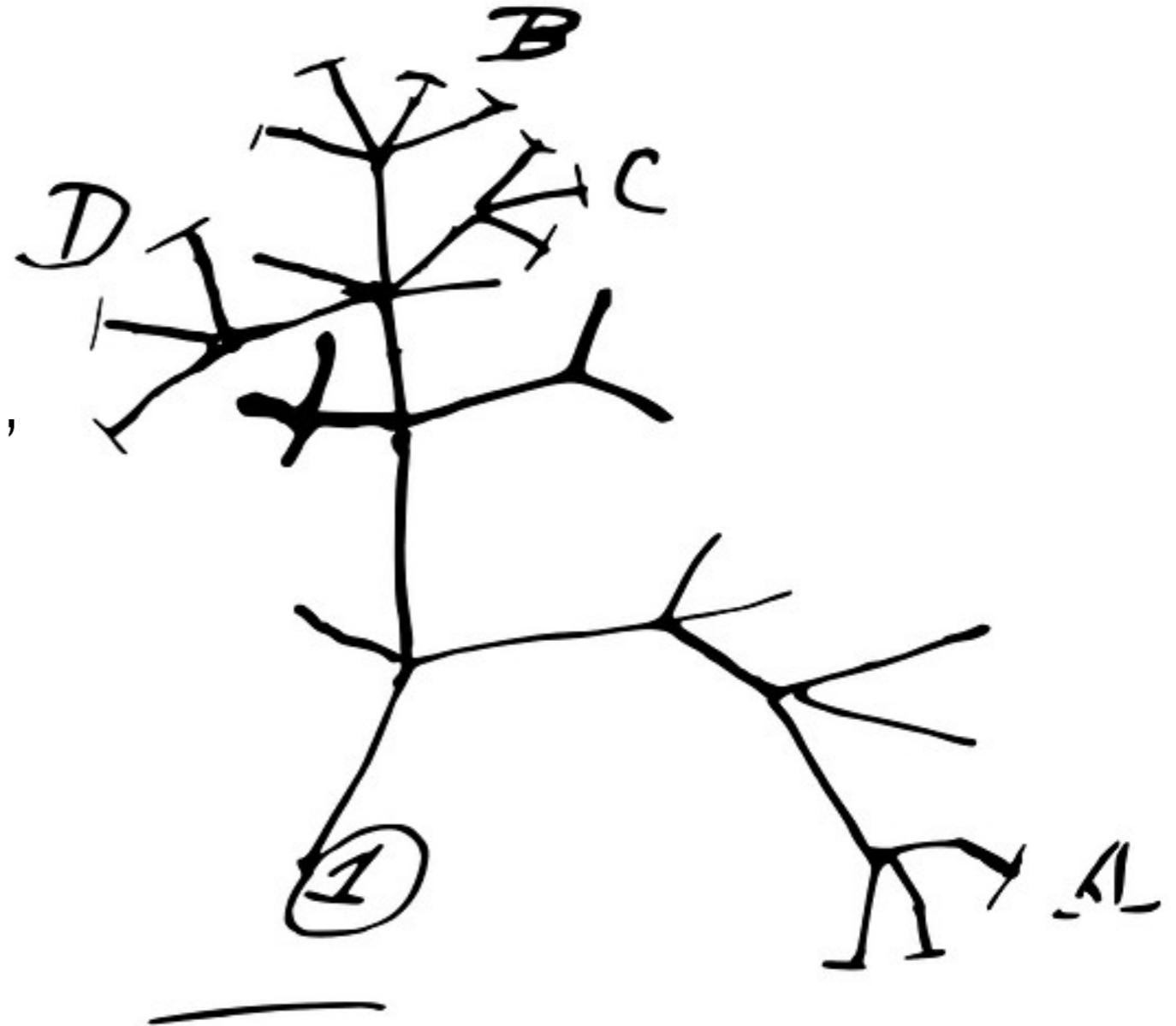
# Darwin and the origin



“...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”

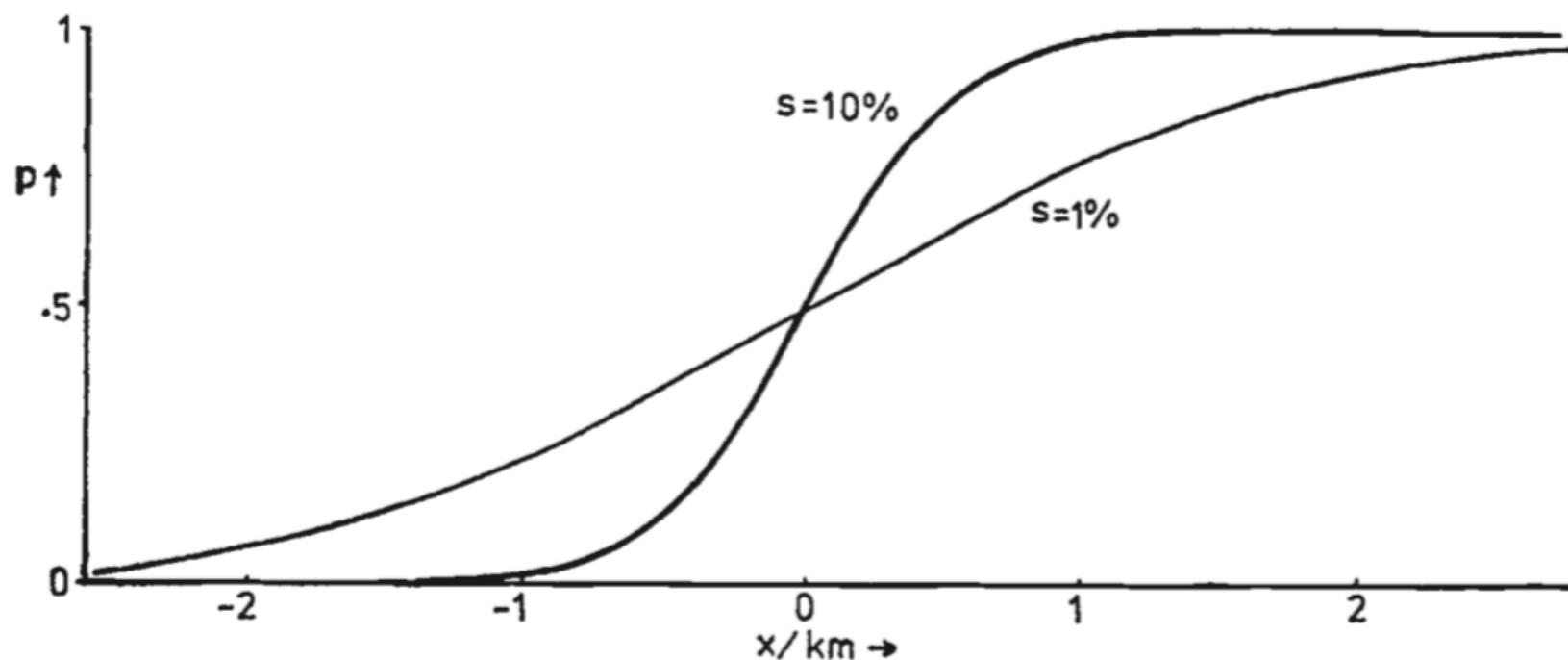


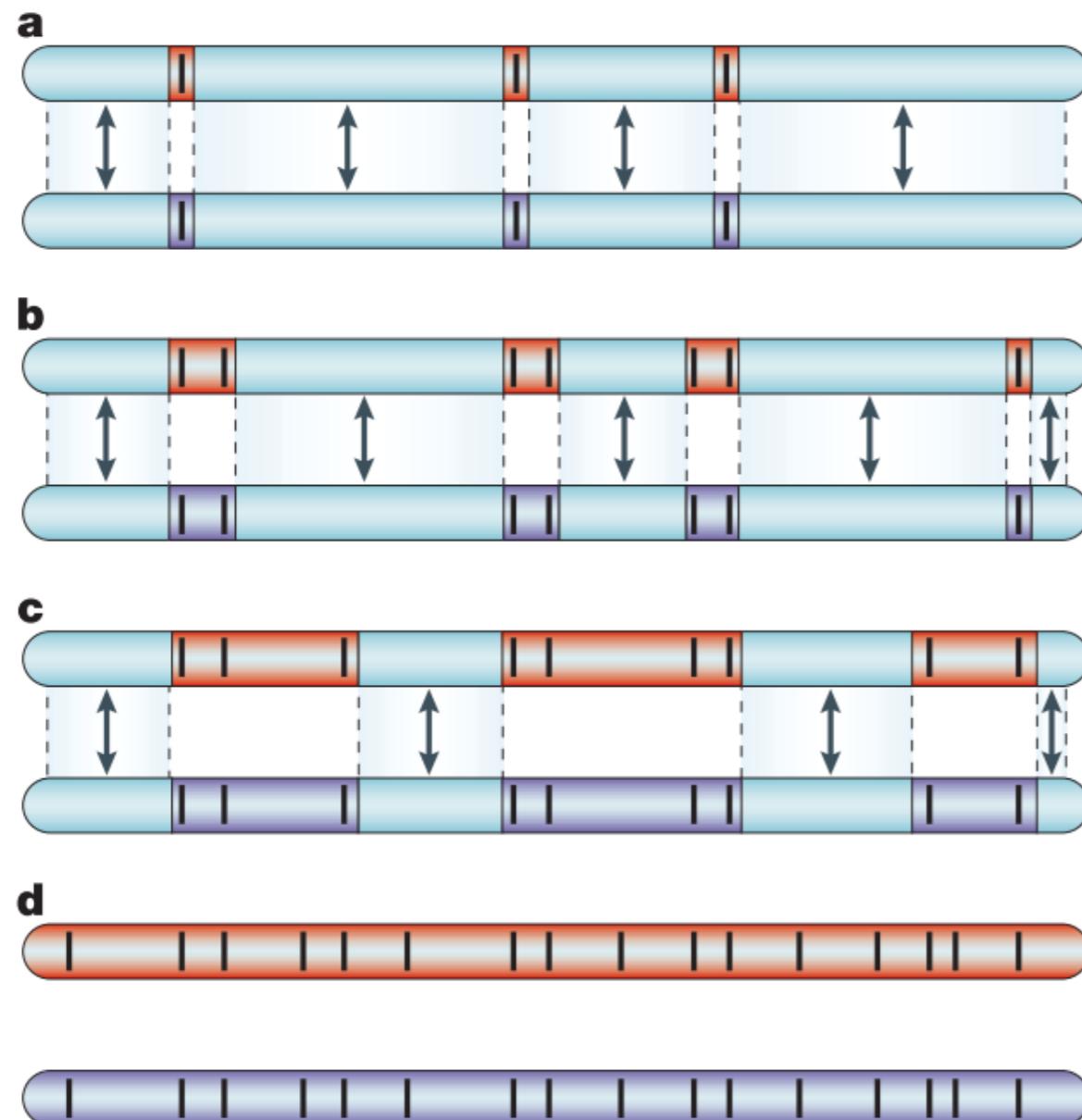
FIG. 1.—Hybrid zones produced by selection against heterozygotes;  
dispersal  $\sqrt{m} = 112 \text{ m.gen.}^{-\frac{1}{2}}$

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

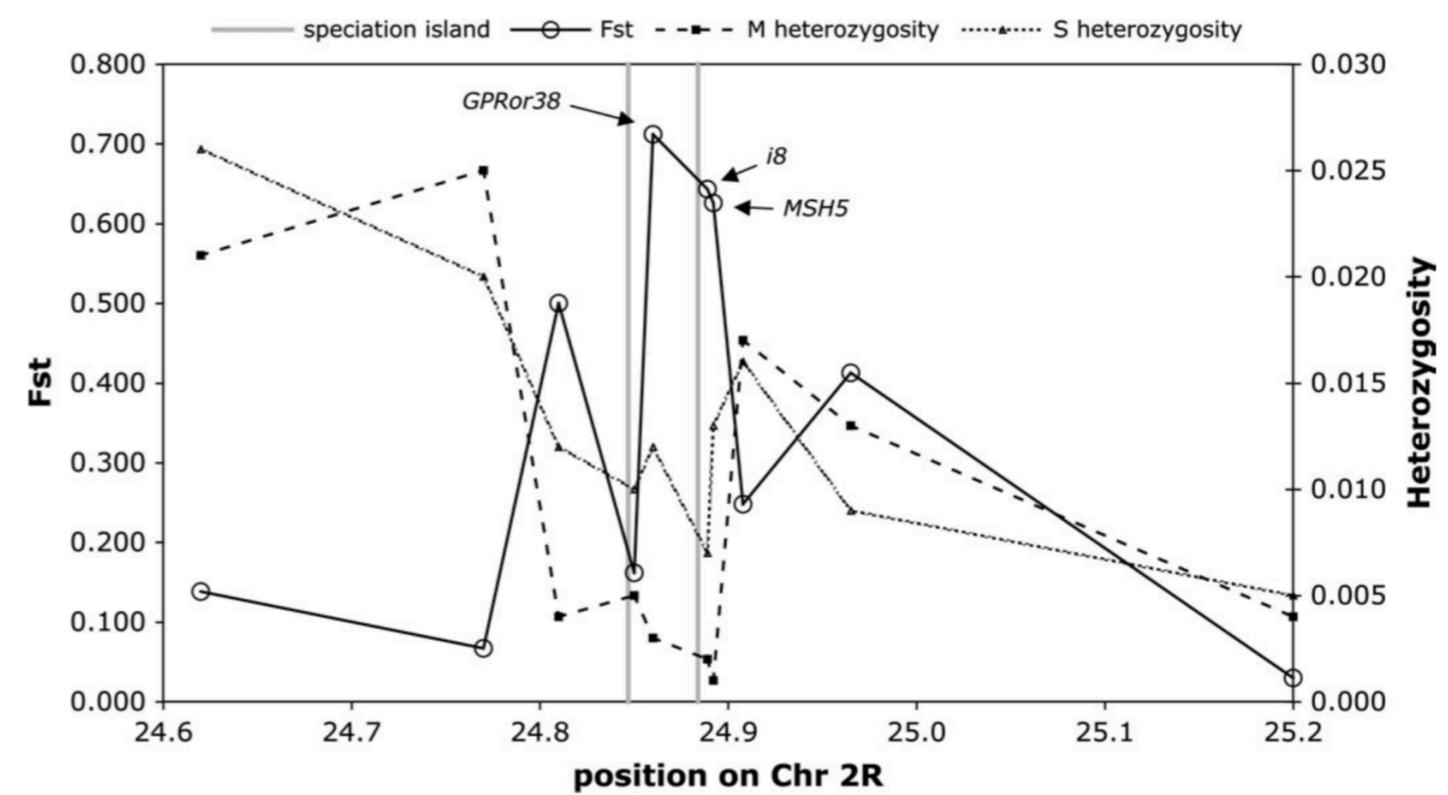
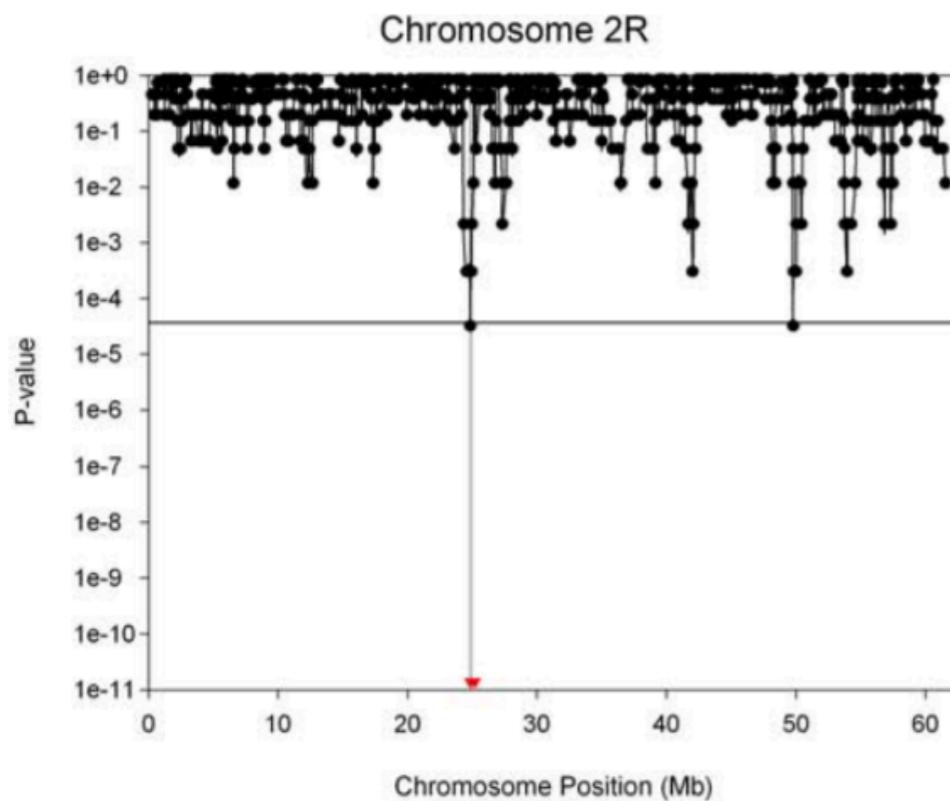
Gene flow continues but linkage builds and divergent regions grow

Complete reproductive isolation evolves

# The rise of speciation islands

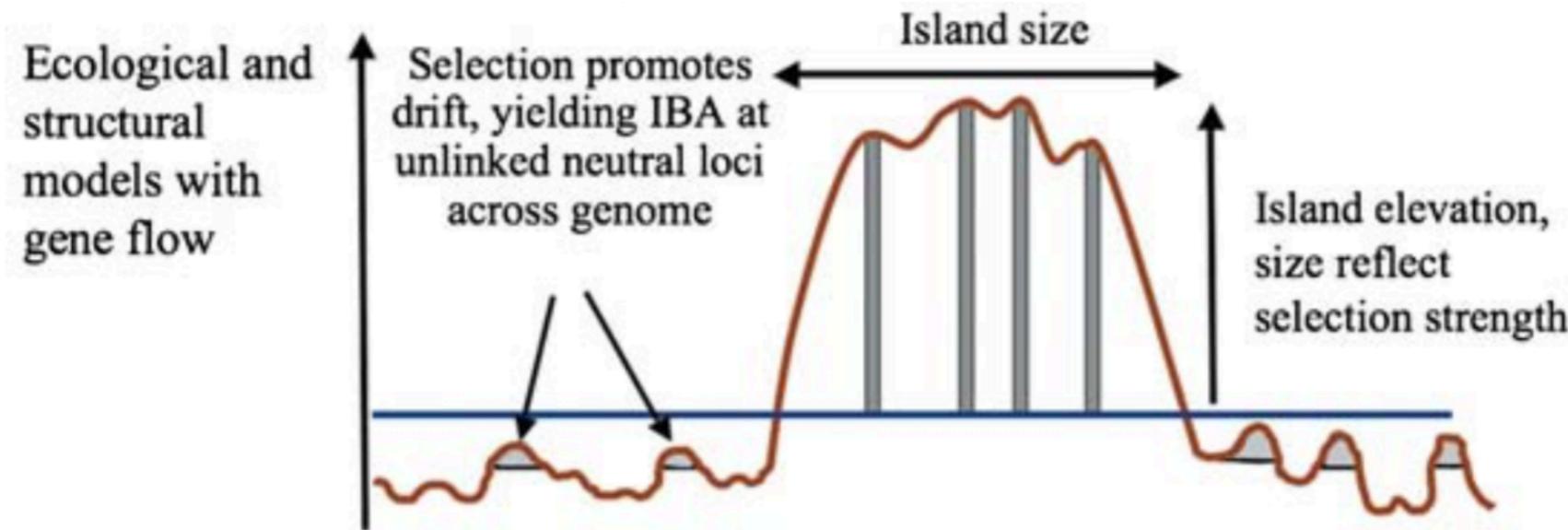


*Anopheles gambiae*  
M + S forms

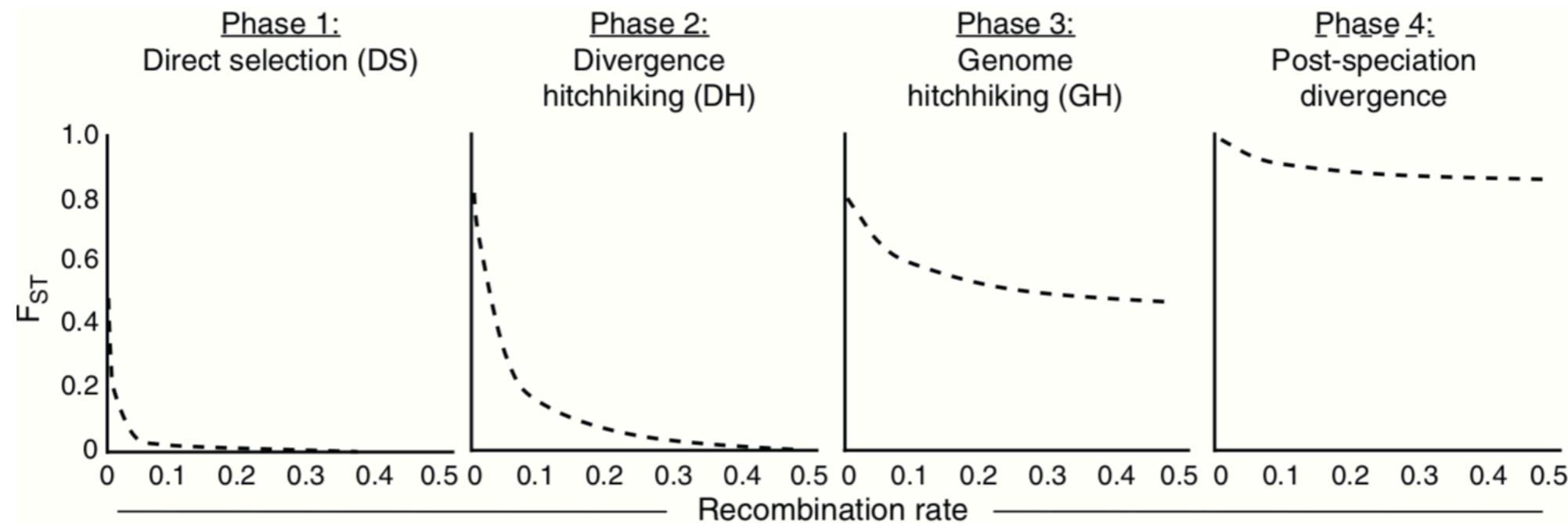


Turner et al (2005) **PLoS Biology**; Turner & Hahn (2007) **MBE**

# Speciation islands and processes



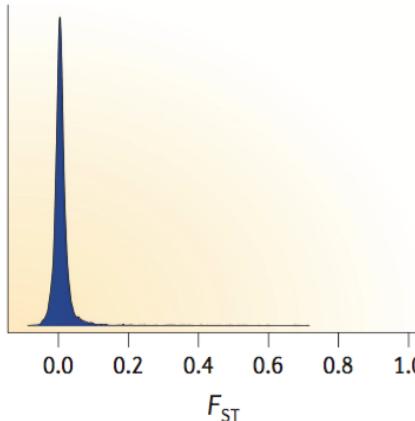
Nosil et al (2009) **Mol Ecol**



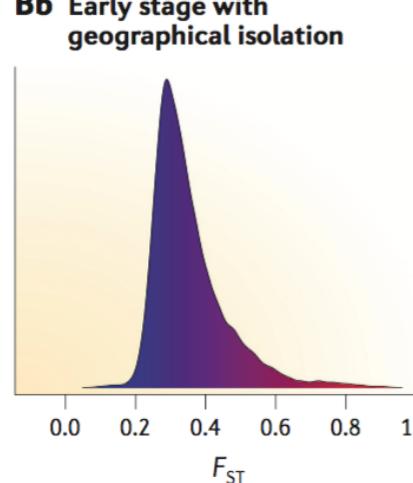
Feder et al (2012) **Trends in Genetics**

# Continuums and islands

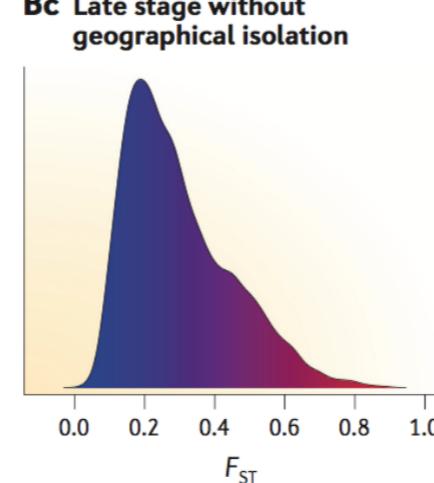
**Ba** Early stage without geographical isolation



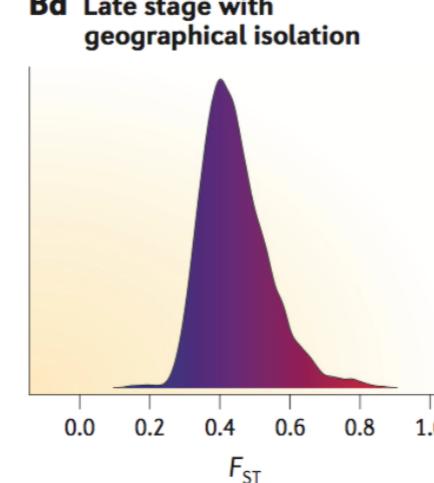
**Bb** Early stage with geographical isolation



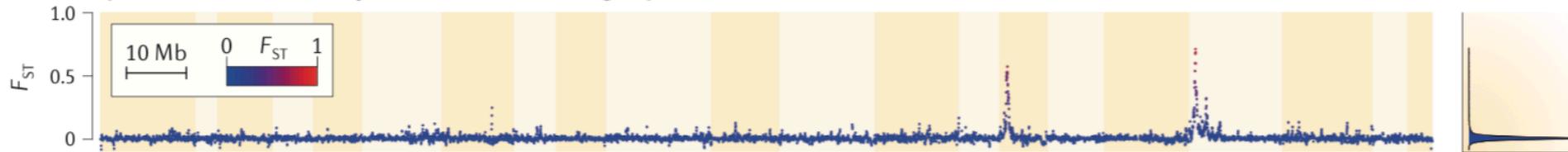
**Bc** Late stage without geographical isolation



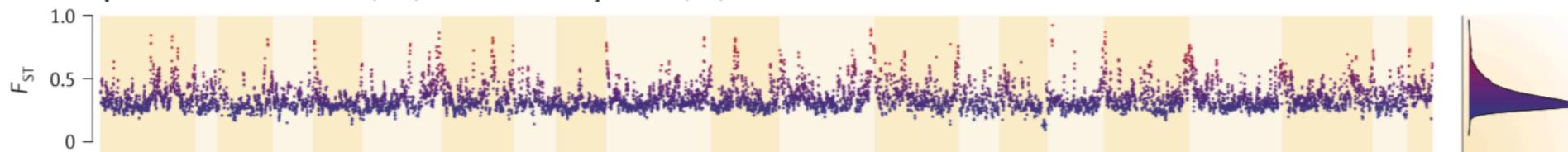
**Bd** Late stage with geographical isolation



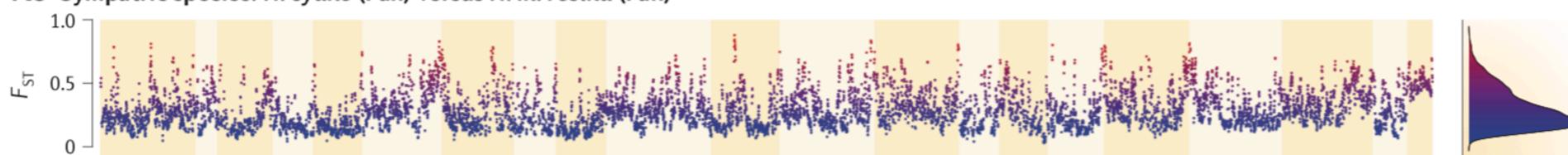
**Aa** Parapatric races: *H. m. amaryllis* (Per) versus *H. m. aglaope* (Per)



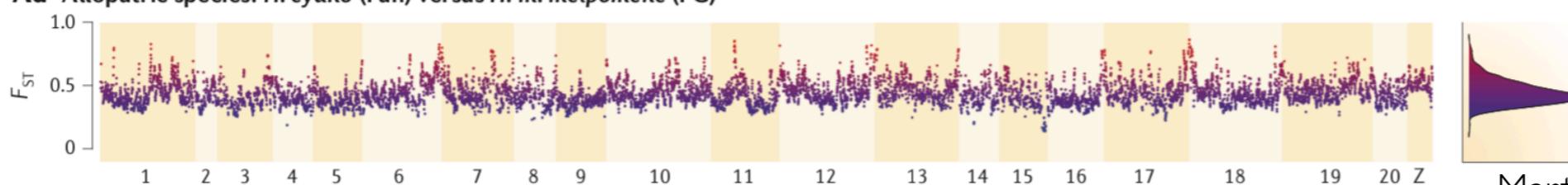
**Ab** Allopatric races: *H. m. rosina* (Pan) versus *H. m. melpomene* (FG)



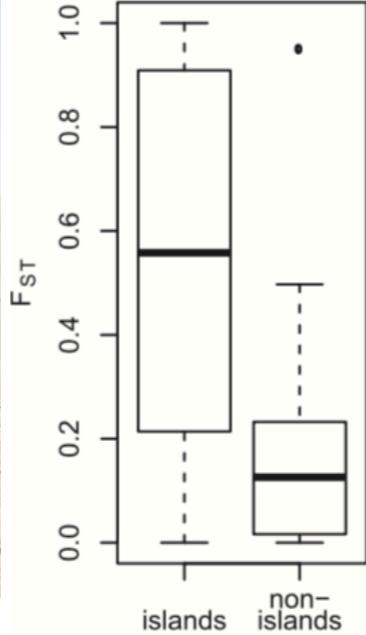
**Ac** Sympatric species: *H. cydno* (Pan) versus *H. m. rosina* (Pan)



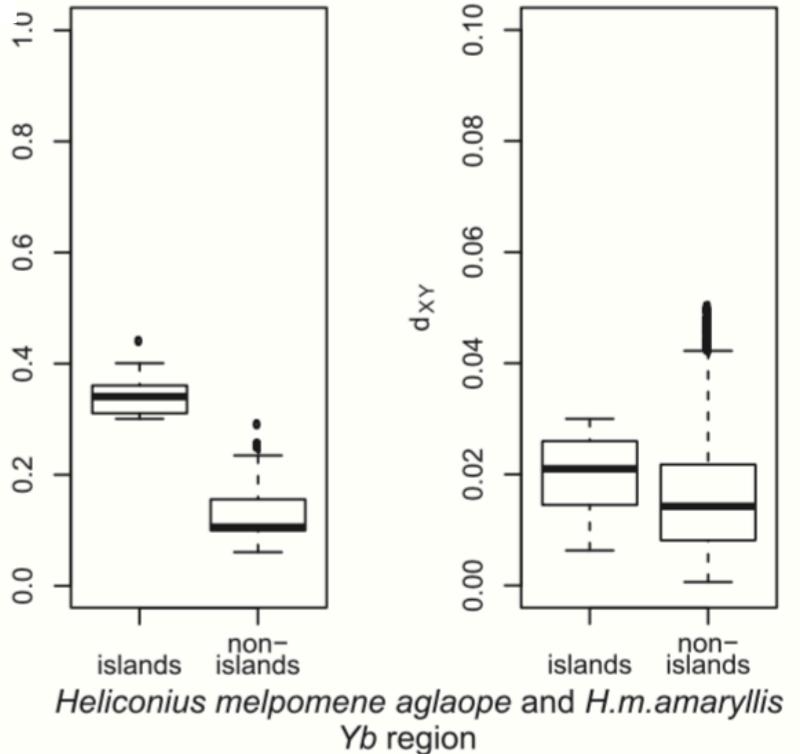
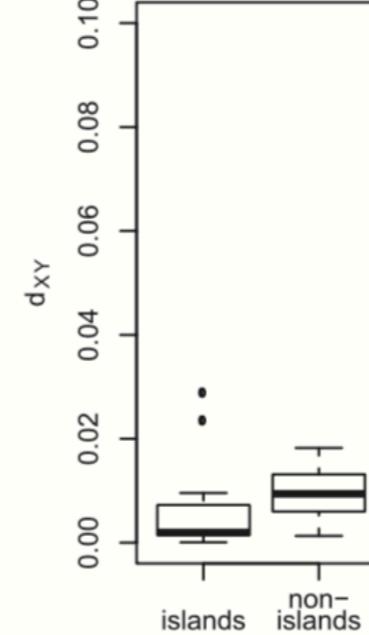
**Ad** Allopatric species: *H. cydno* (Pan) versus *H. m. melpomene* (FG)



# Mirages and alternative explanations



*Anopheles coluzzii* and *A. gambiae*

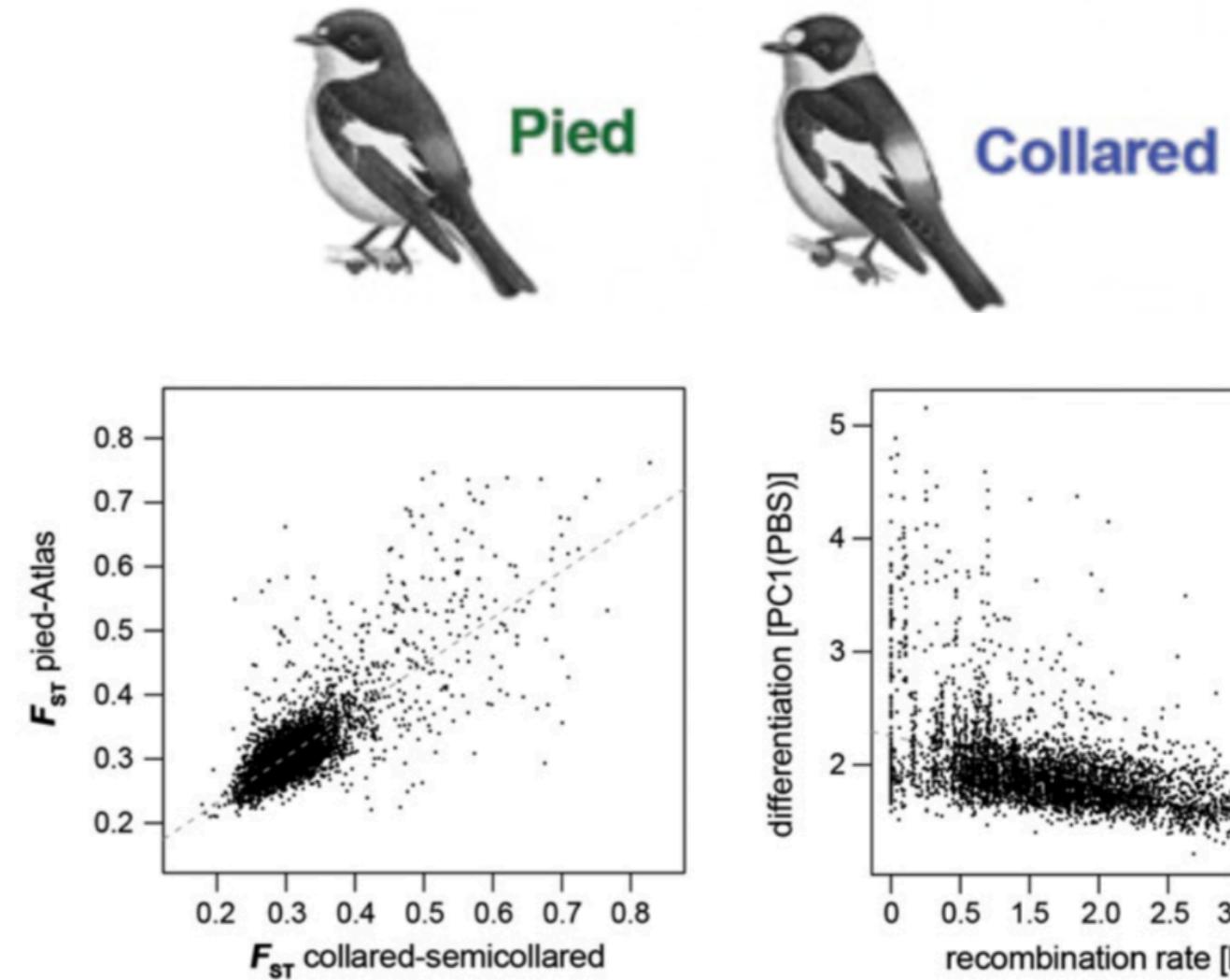
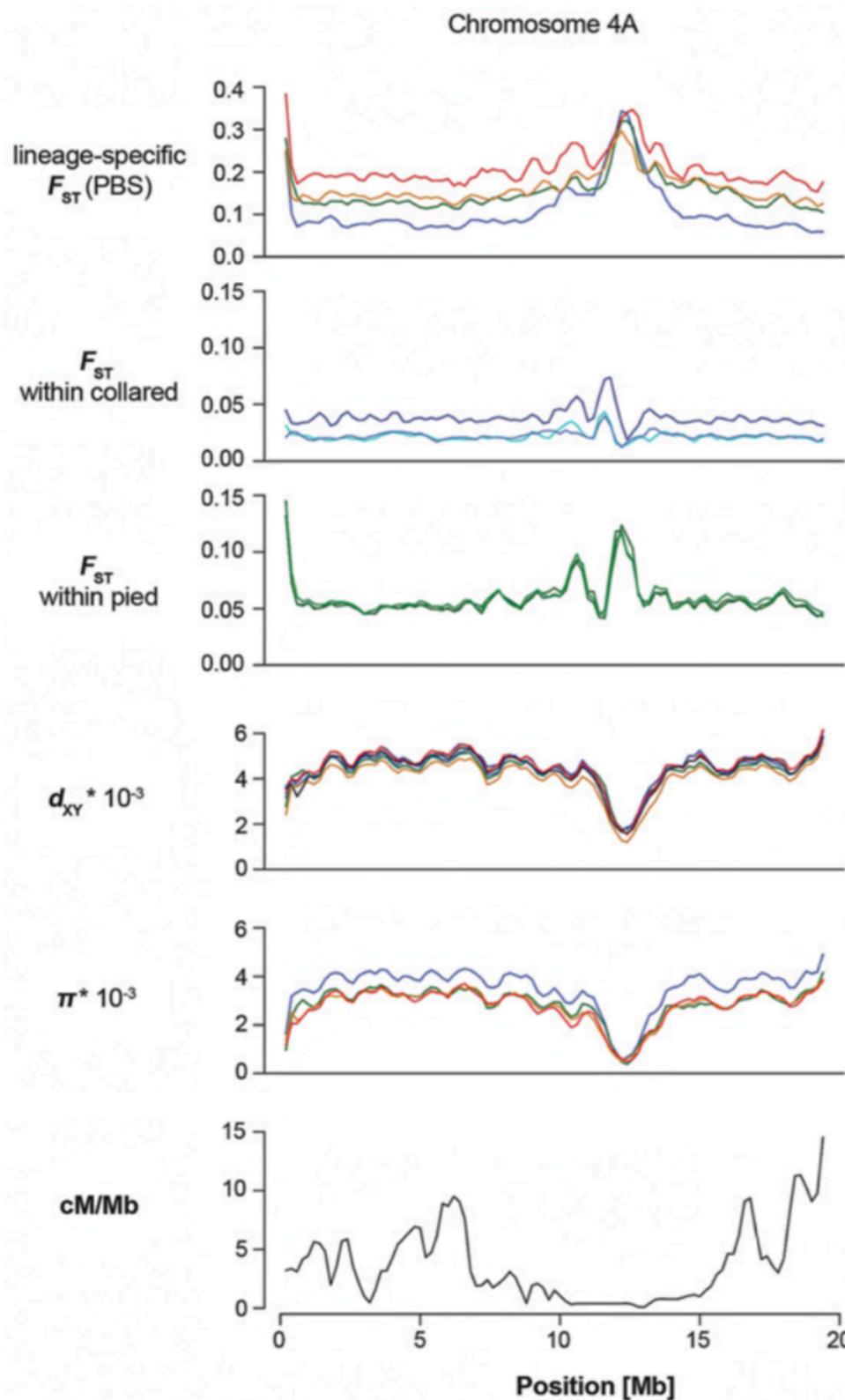


*Heliconius melpomene aglaope* and *H.m. amaryllis*  
Yb region

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

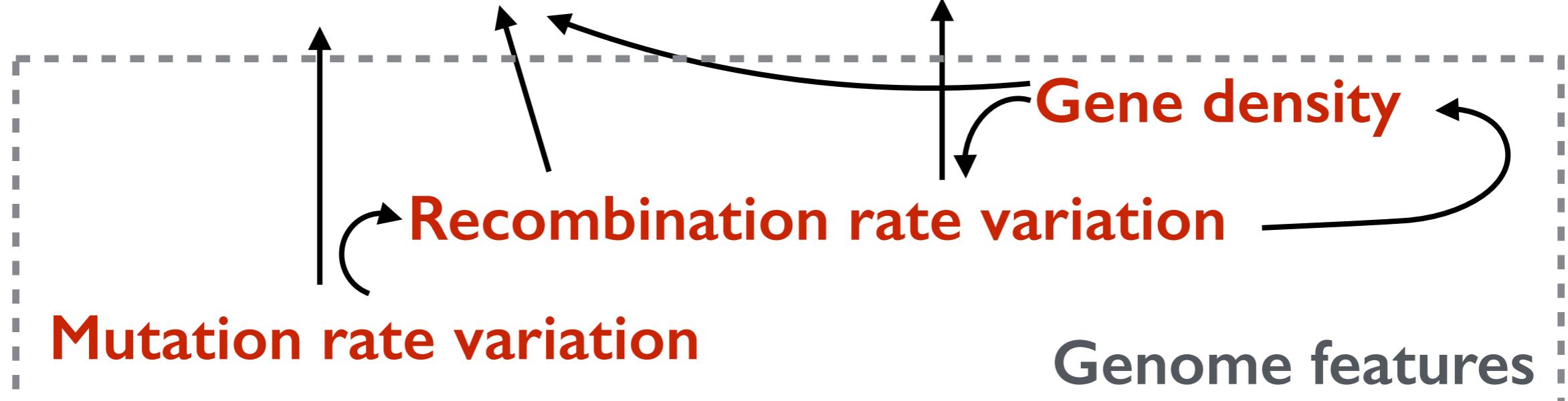
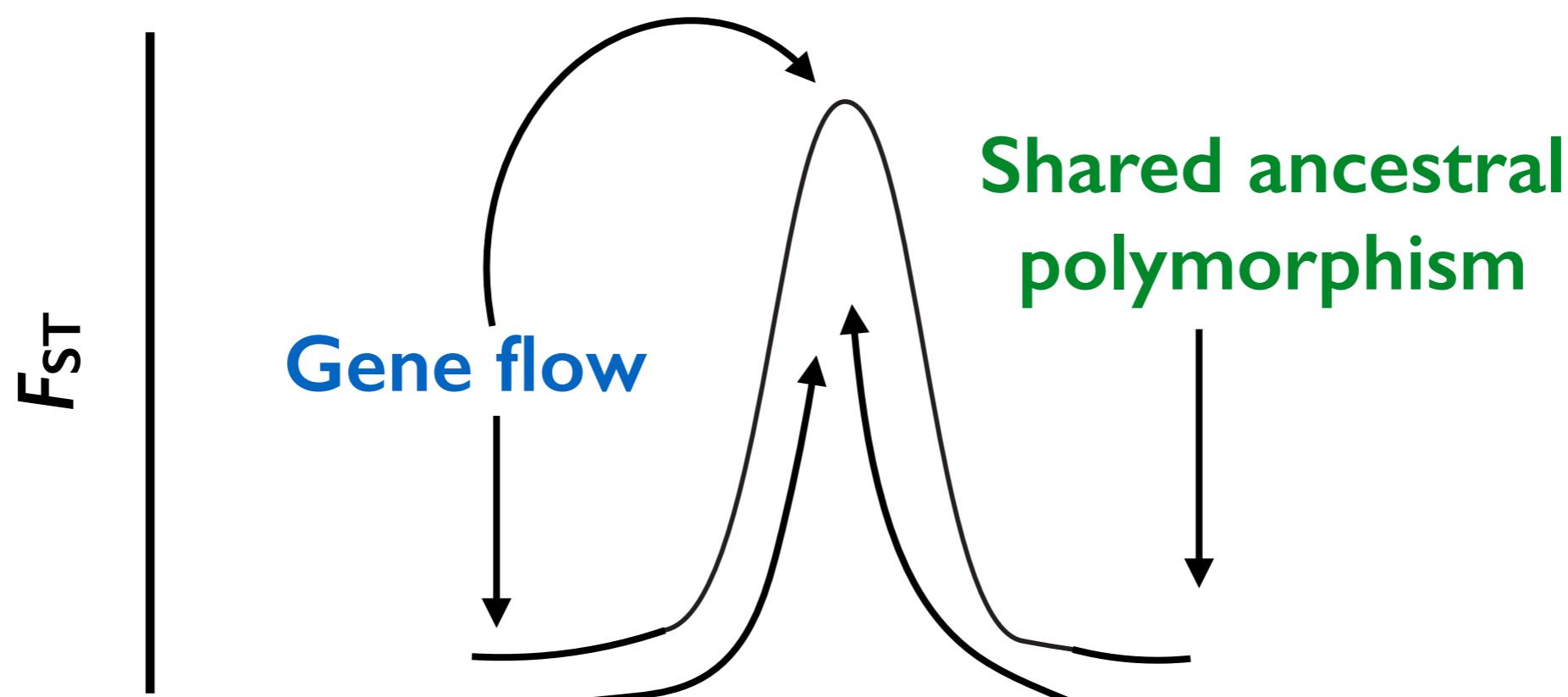
Noor & Bennett (2008) **Heredity**  
Cruickshank & Hahn (2014) **Mol Ecol**

# Linked selection and recombination

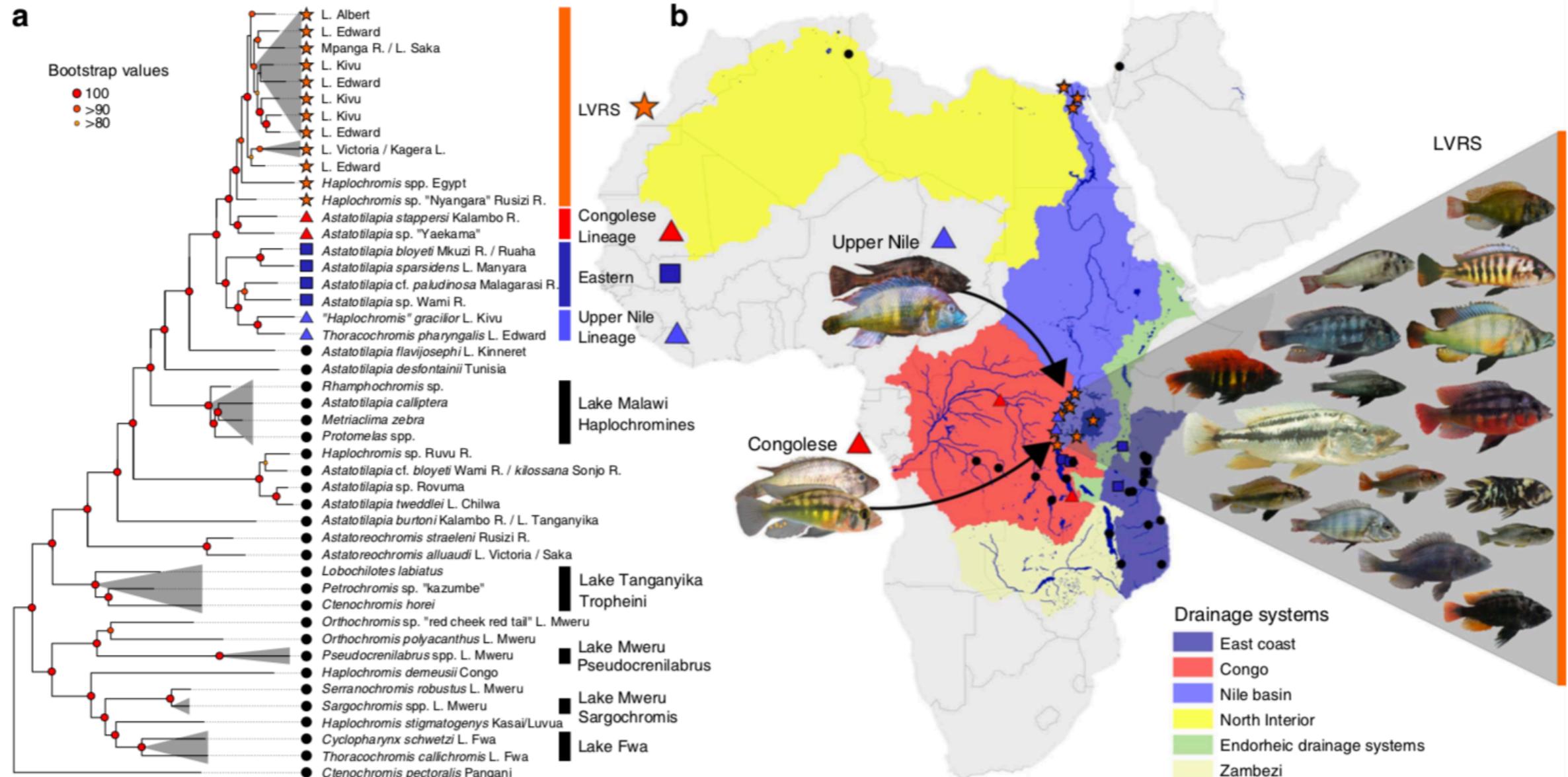


# Confounding factors

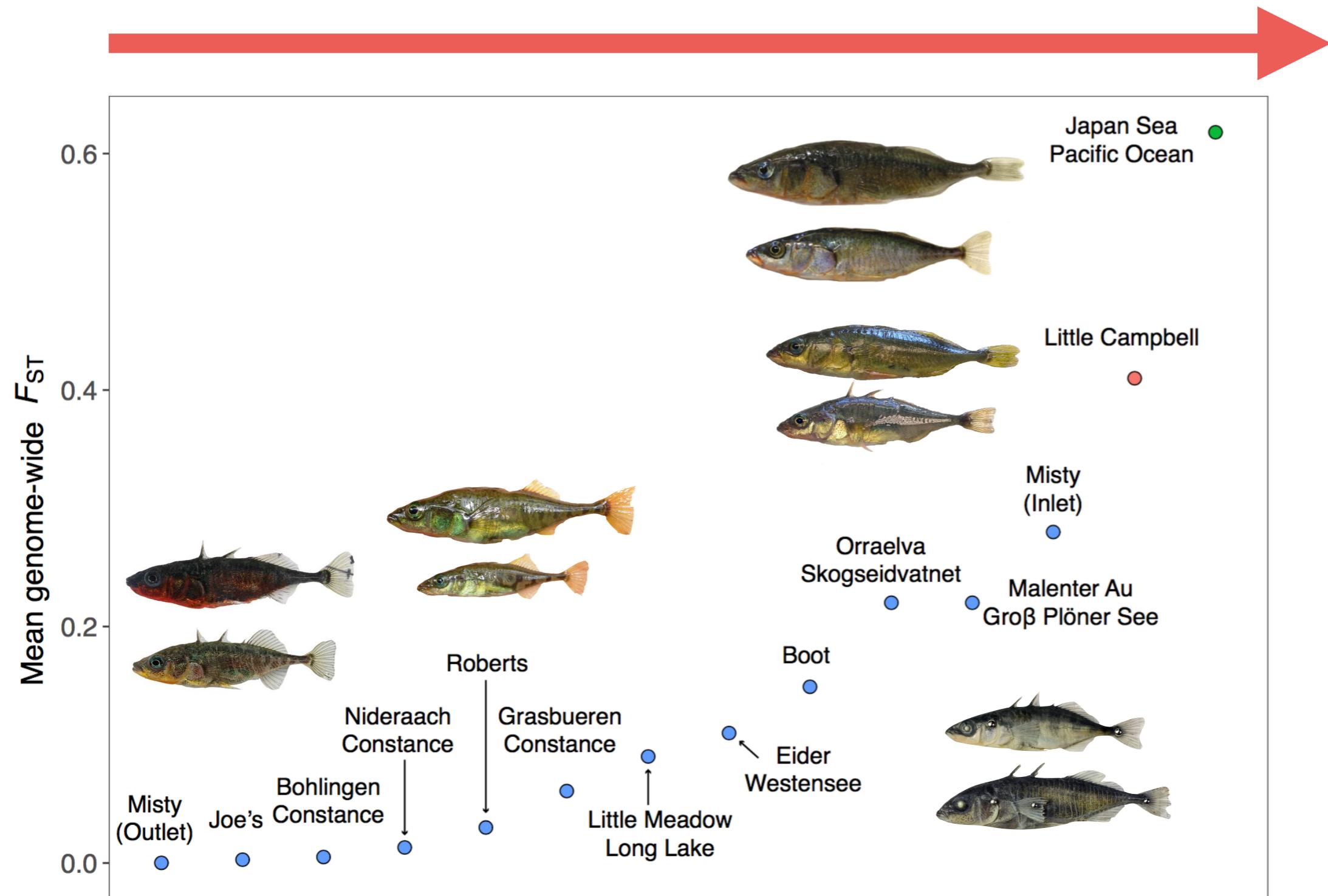
Demographic history



# The Lake Victoria cichlid radiation



# The stickleback speciation continuum



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

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

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

Rank order

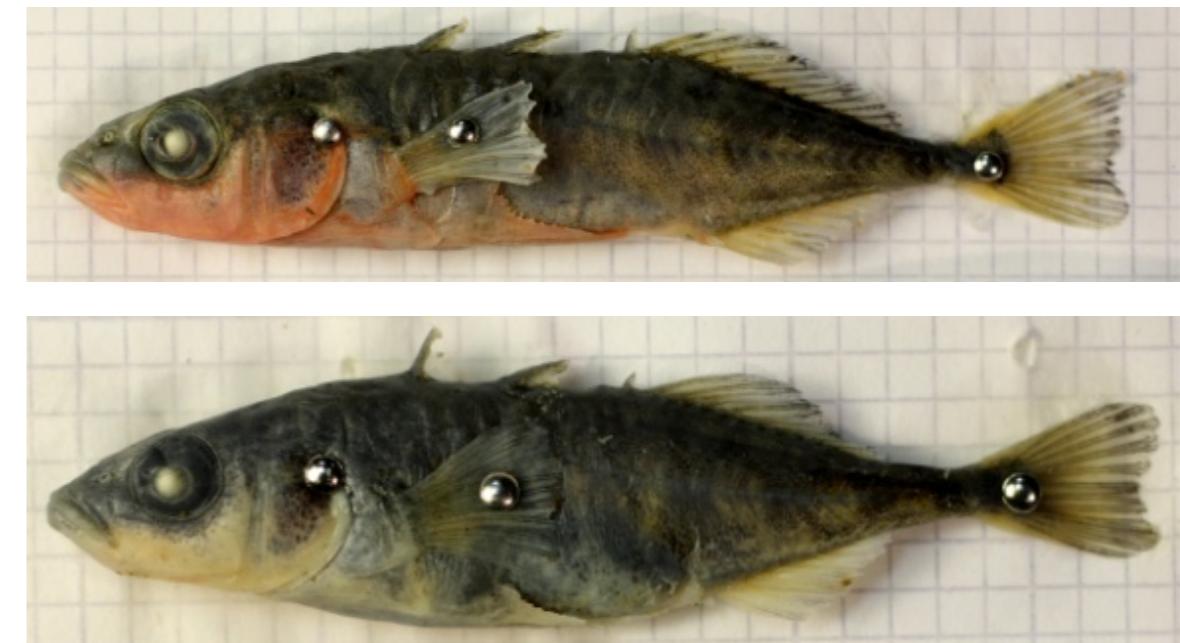
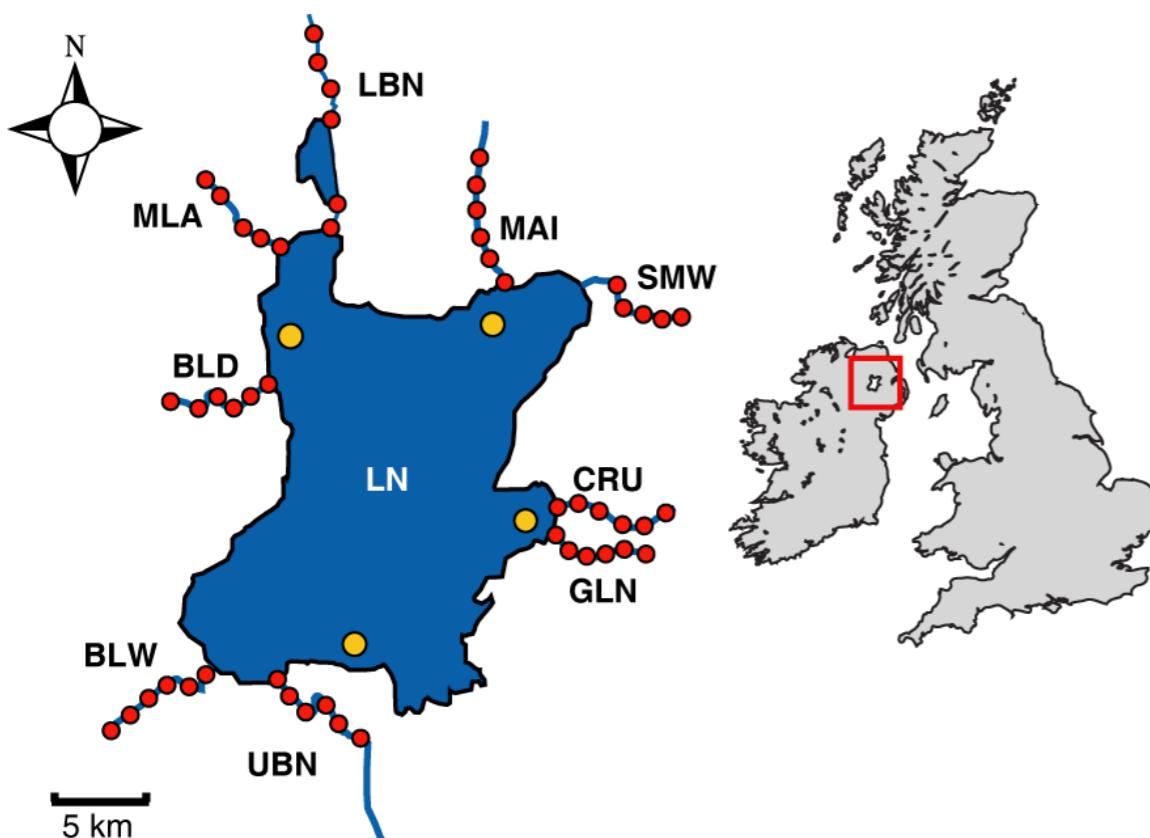
● Anadromous-stream ● Japanese ● Lake-stream

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

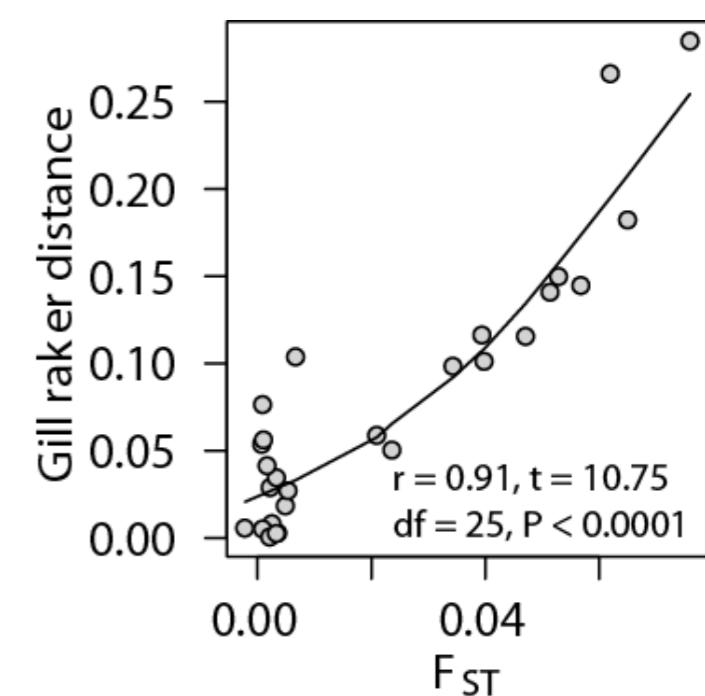
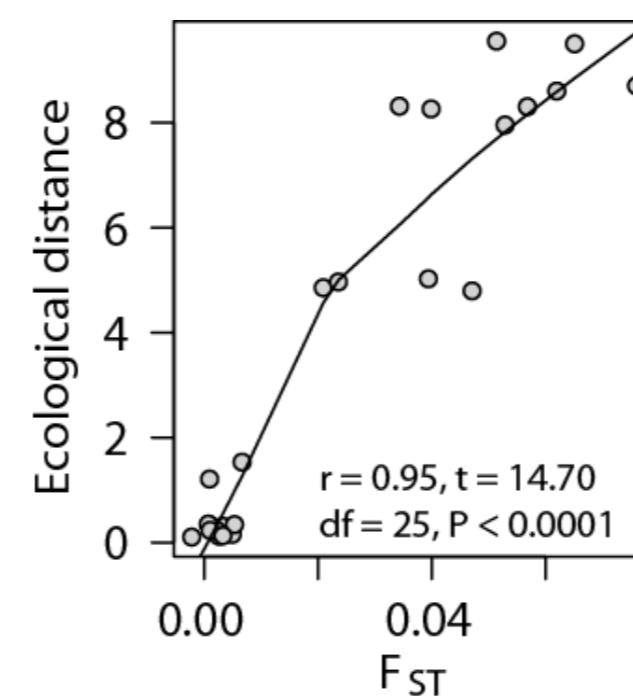
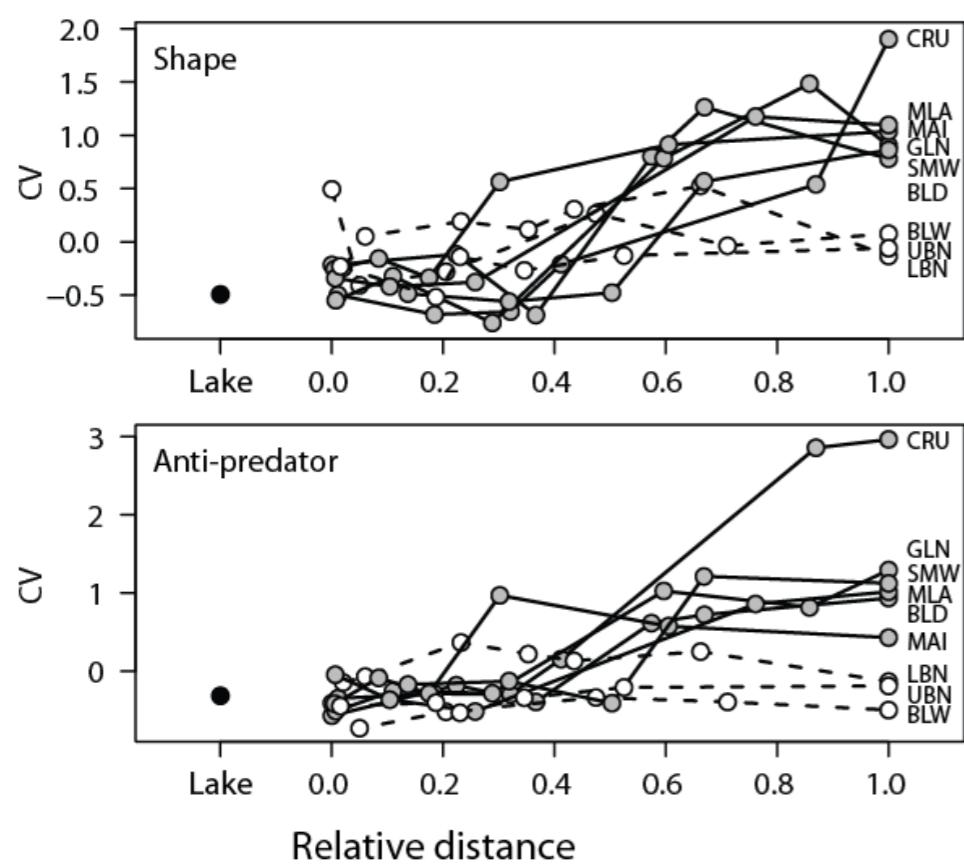
Kusukabe et al (2017) **Mol Ecol**

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

# Parallel & non-parallel lake-stream stickleback evolution



*Gasterosteus aculeatus*



# Late stage speciation in sticklebacks



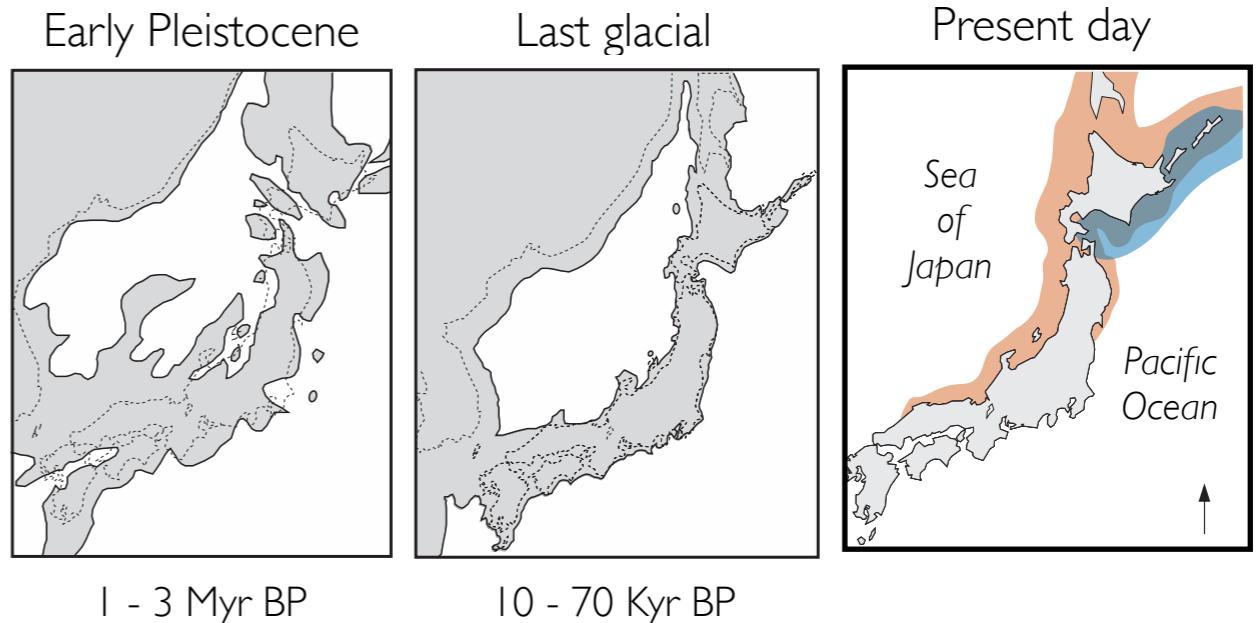
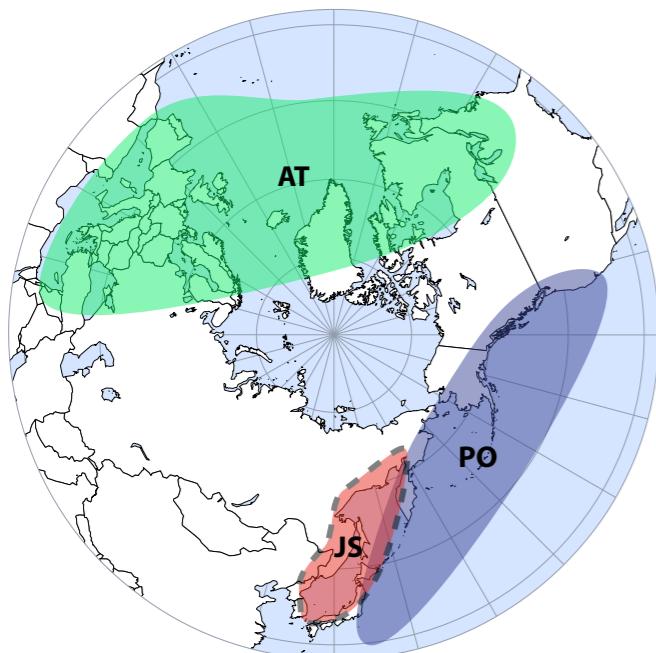
Three-spined stickleback

Pacific Ocean    Atlantic Ocean

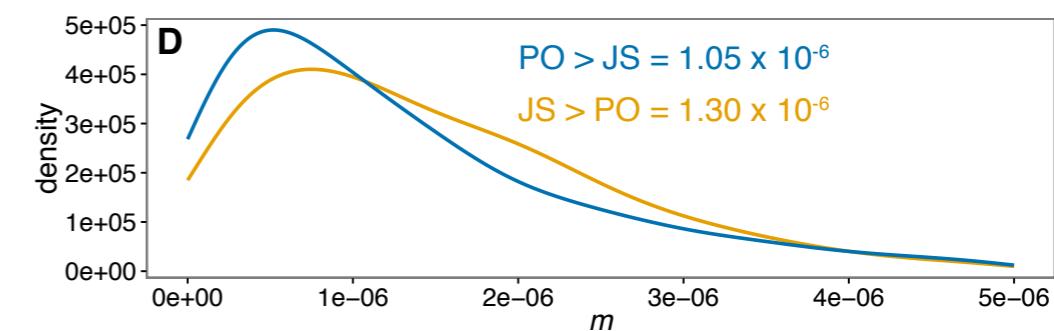
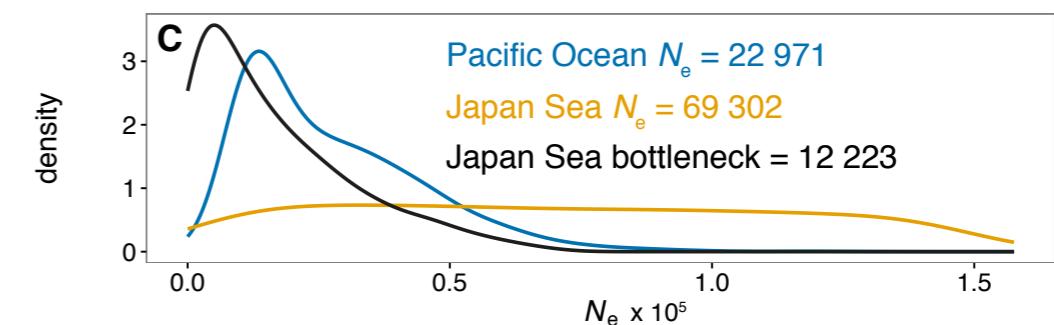
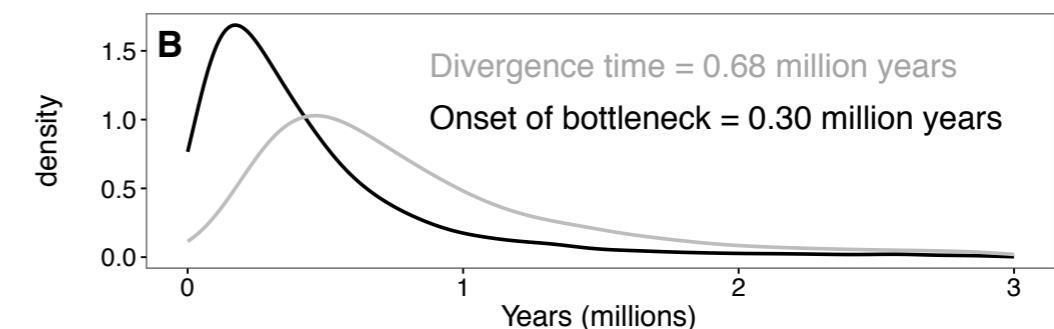
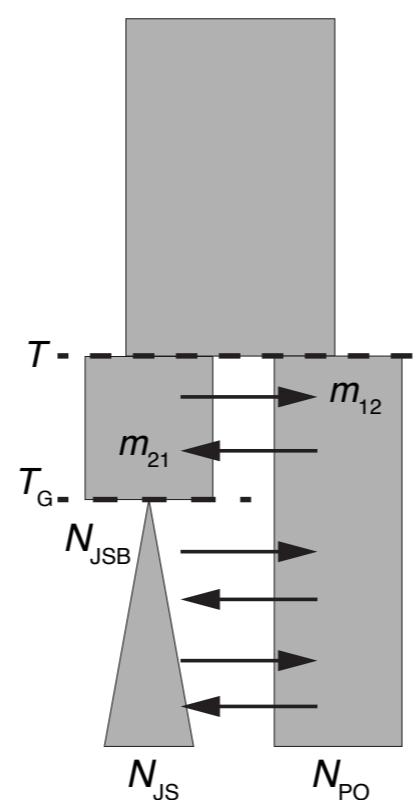


Japan Sea stickleback

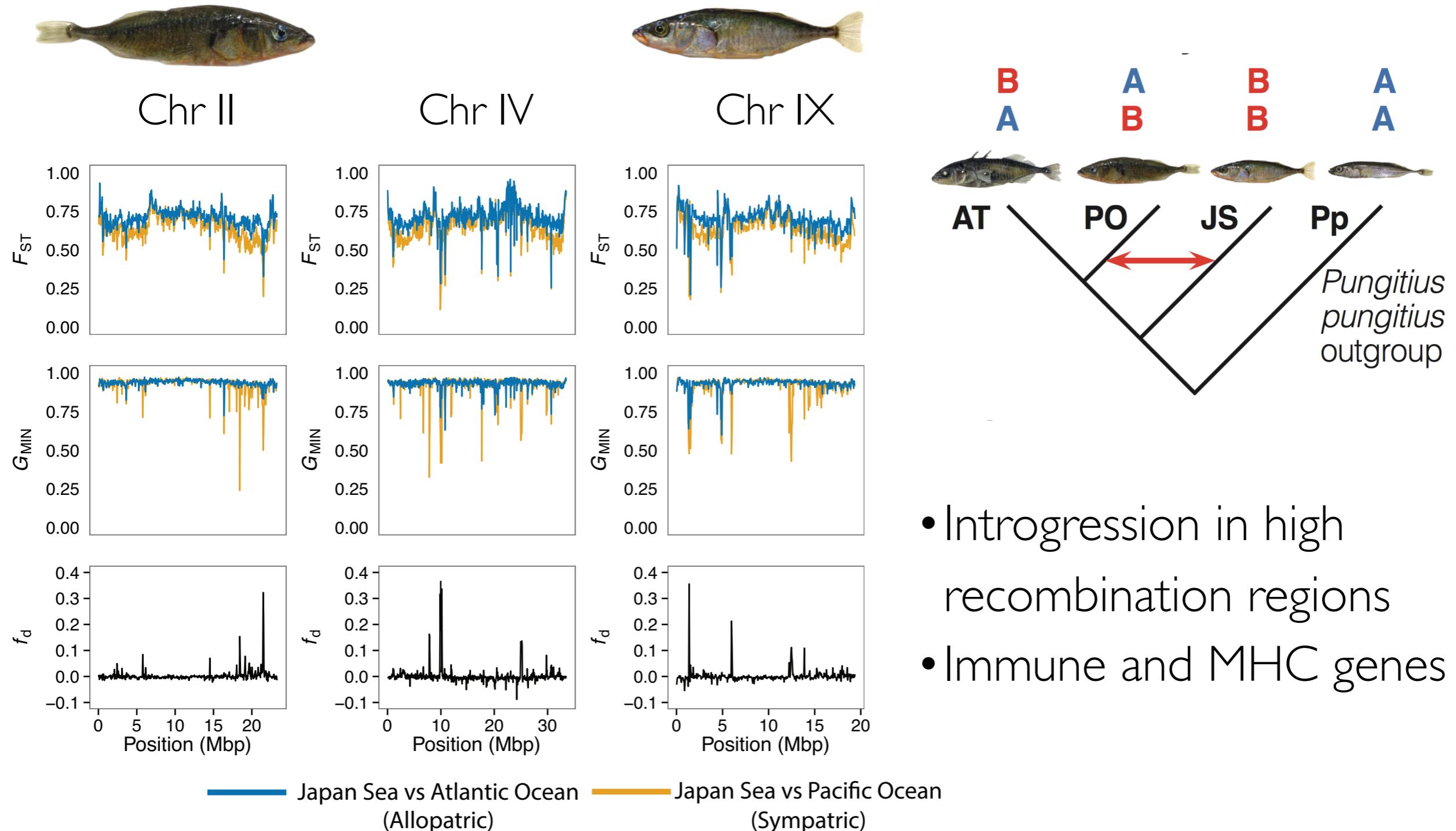
Sea of Japan    Sea of Okhotsk



**A** Constant migration + bottleneck



# Introgression localised in the genome



# House sparrow

*Passer domesticus*



# Spanish sparrow

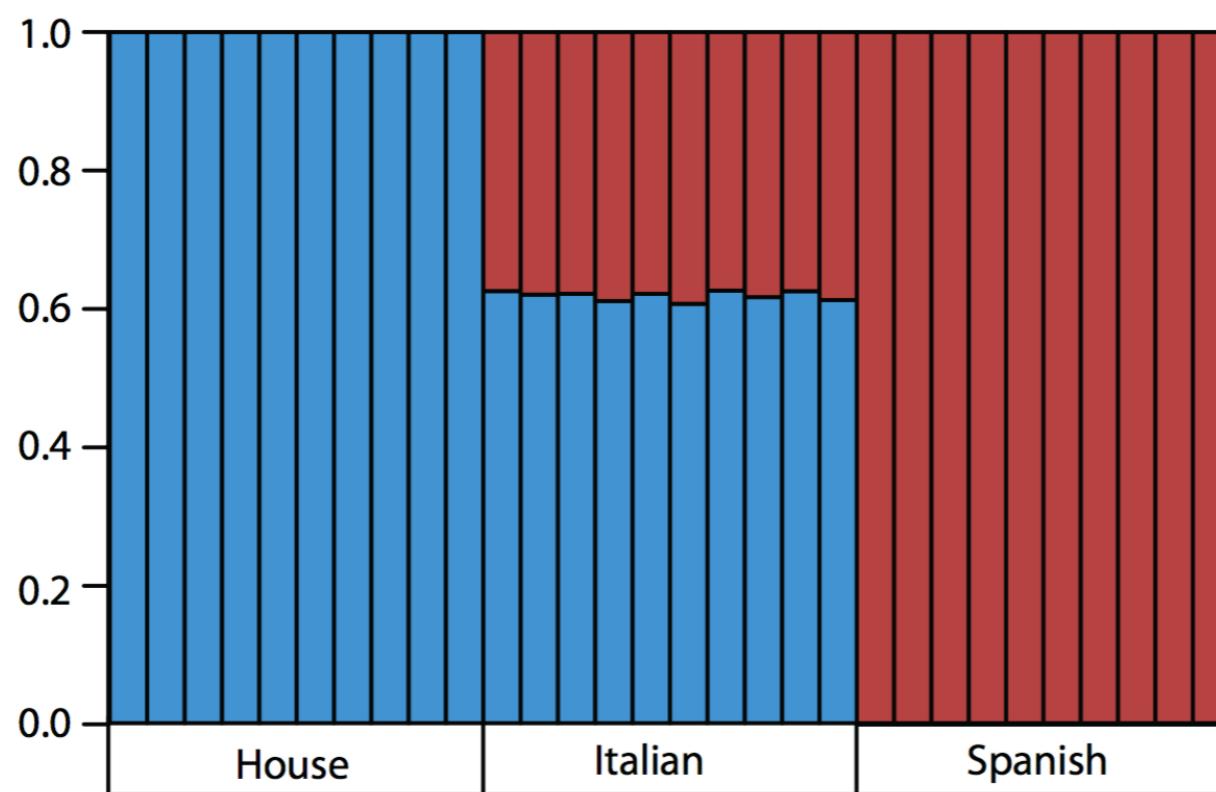
*Passer hispaniolensis*

# Italian sparrow

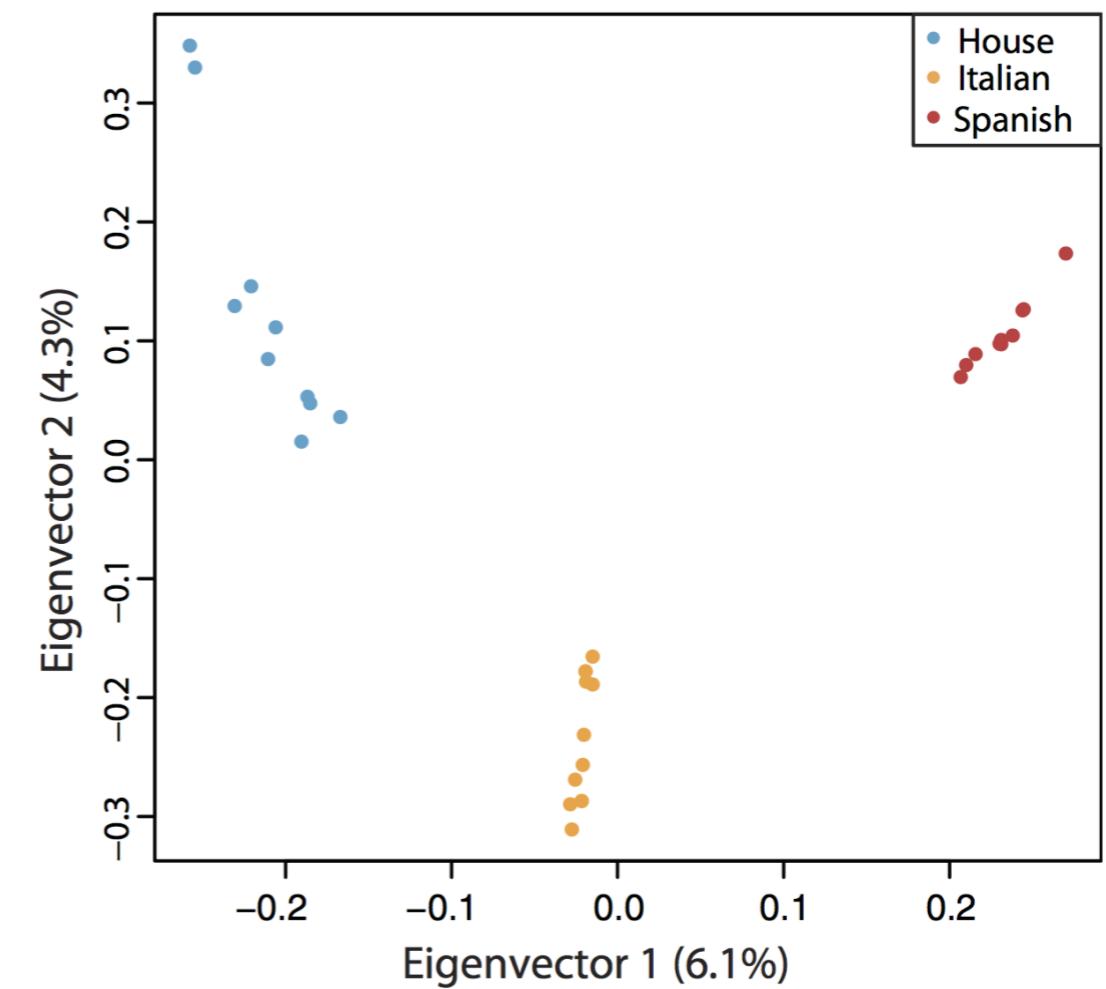
*Passer italiae*



# Italian sparrows are a hybrid species



Analyses based on LD pruned, high quality  
270 K SNPs





# A confusing field - what is the way forward?



TARGET  
**Inter-  
findin**

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

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



Jochen B. W. Wolf<sup>1</sup>

Interpreting differentiation landscapes  
in

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

Reto<sup>1</sup>

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

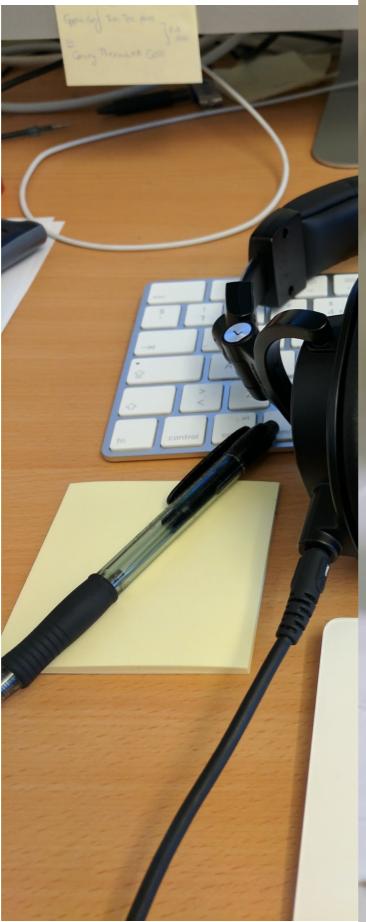
**[speciationgenomics.github.io](https://speciationgenomics.github.io)**

# 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

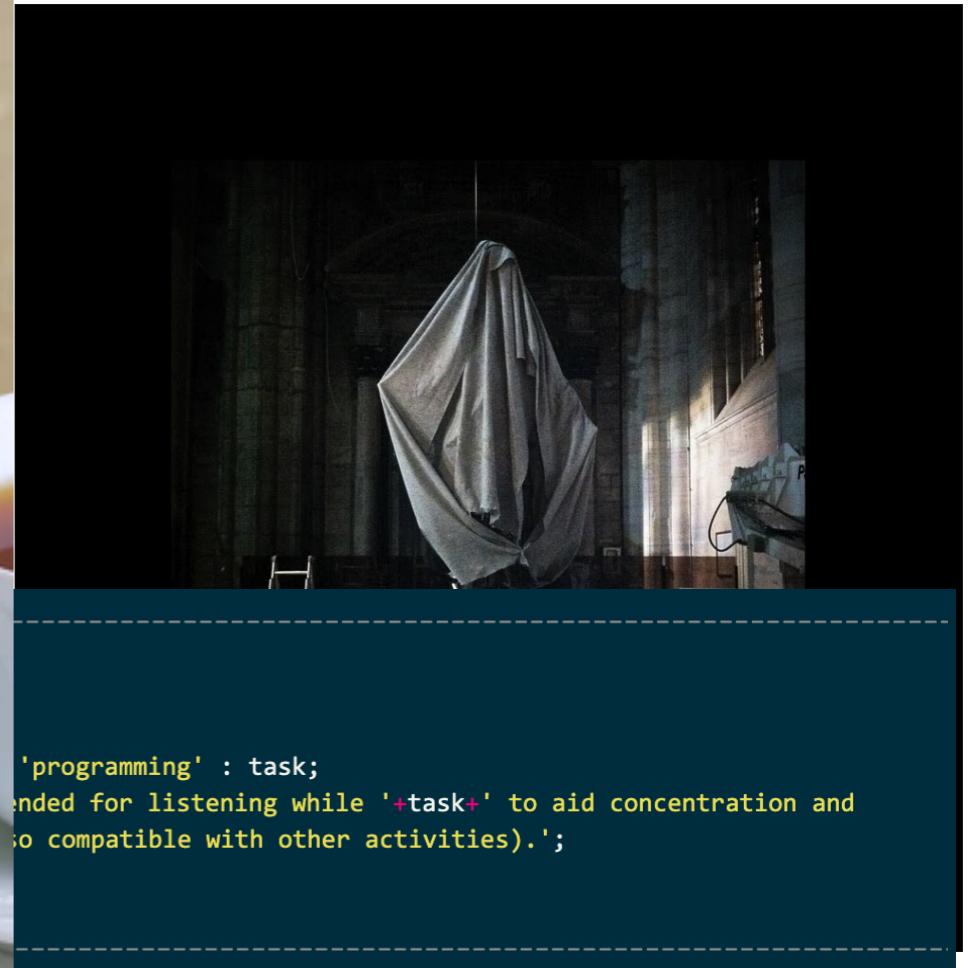
**[speciationgenomics.github.io](https://speciationgenomics.github.io)**

# 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

