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# Divergent evolution of genetic sex determination along environmental gradients

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## **Background information**

Main question: How do genetic sex determination systems evolve when gene expression is influenced by environmental conditions?



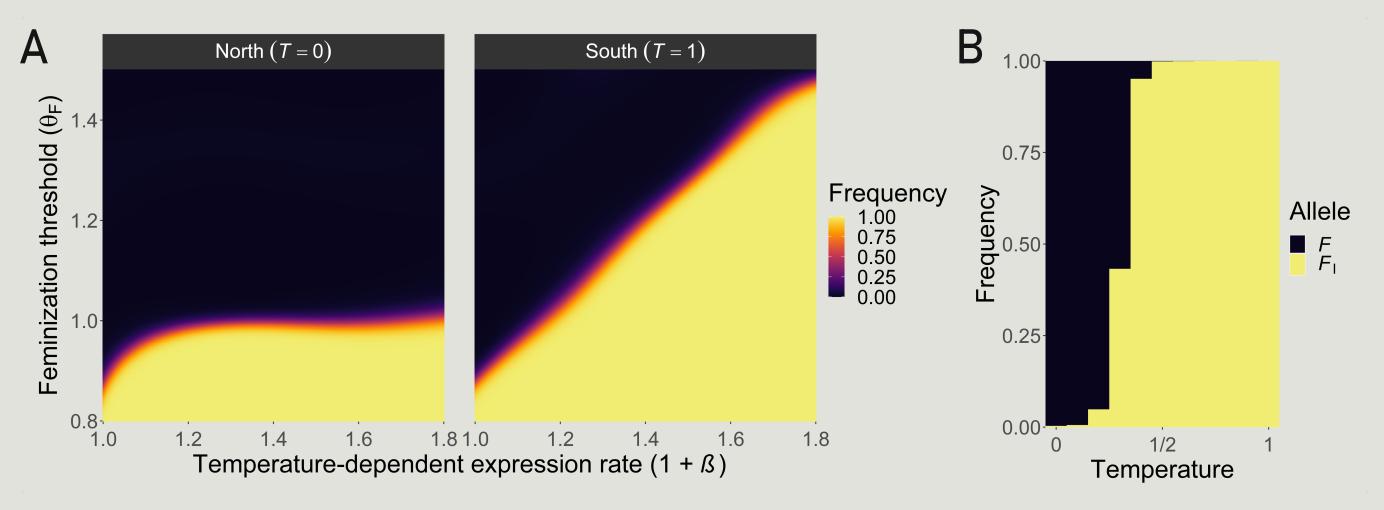
**←** Environment **→** 

Relative fitness

- Sex determination is often affected by genetic and environmental factors
- Environmental perturbance may lead to intersexual development with zero fitness
- Unclear how spatial heterogeneity affects evolution of sex determination systems
- Possible link between environmental variation and polygenic sex determination

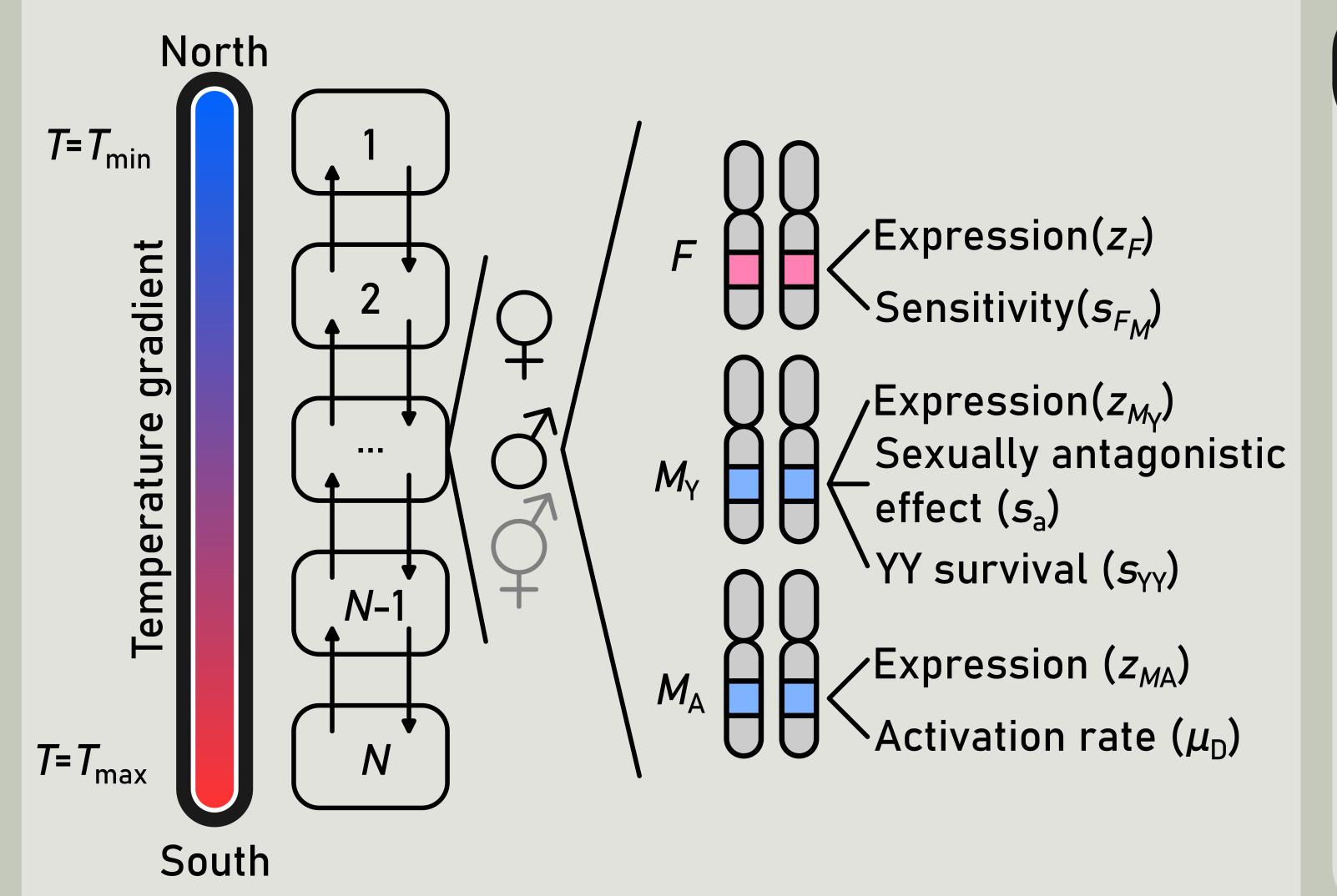
# Evolution of a dominant feminizer $F_{i}$

 $F_{\rm I}$ : fully insensitive to  $M_{\rm Y}$  and  $M_{\rm A}$ , net expression exceeds  $\theta_{\rm F}$ , so that carriers are always female



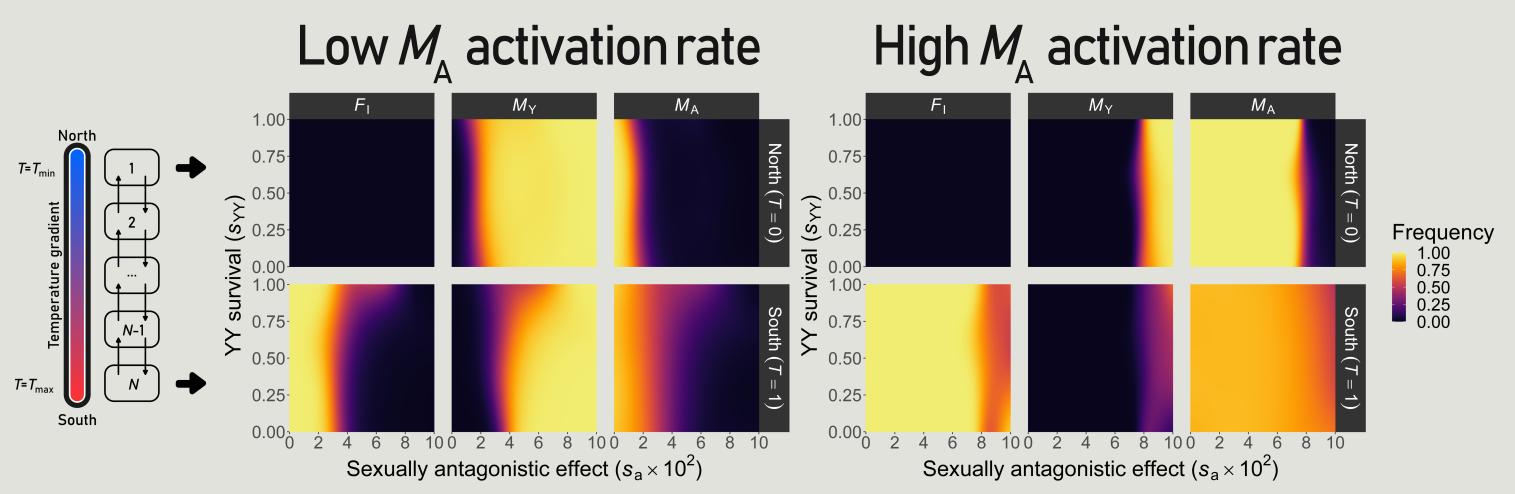
- (A)  $F_{\parallel}$  evolves when feminization threshold  $\theta_{\rm F}$  is low (left) or when temperature-dependent overexpression becomes sufficiently strong (right)
- (B) Temperature-dependent invasion of  $F_{\rm I}$  may be restricted to warmer demes; environmental variation leads to within-population differentiation

#### Model overview



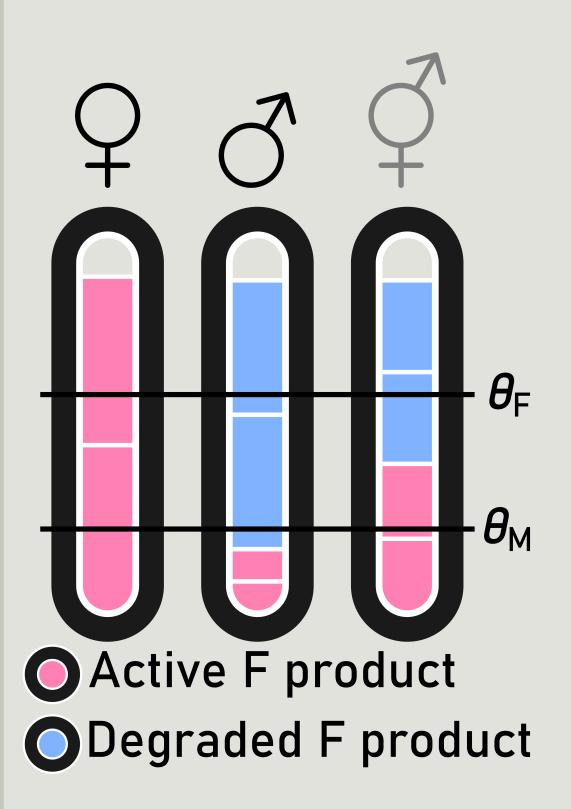
- Agent-based simulations
- Demic population with dispersal
- Non-overlapping generations
- Ancestral Y-chromosome  $M_{\gamma}$  with fitness effects
- *De novo* evolution of  $M_A$

## Frequency gradients at multiple loci



- $F_1$  frequency gradients shaped by temperature; net expression too low at T=0 for  $F_1$  to evolve, but sufficient at higher temperatures
- $M_{\gamma}$  versus  $M_{\Delta}$  polymorphism: sexual antagonistic selection maintains  $M_{\gamma}$  over  $M_{\Delta}$  in absence of  $F_{\gamma}$ ; costs in females and reduced viability in YY homozygotes drive  $M_{\gamma}$  loss, followed by fixation of  $M_{\Delta}$  in presence of  $F_{\gamma}$

# Sex determination gene functions and evolution

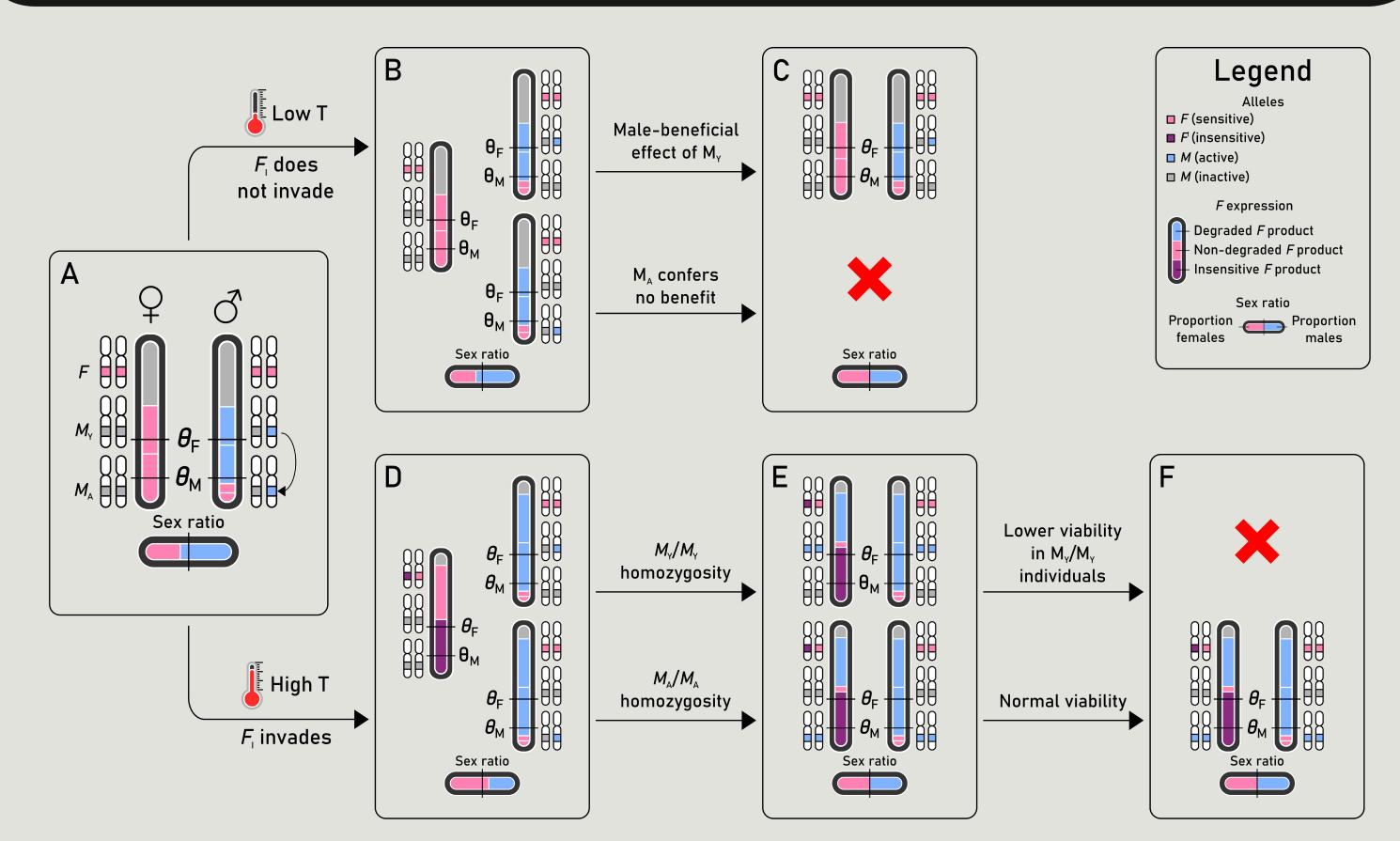


- Sex is determined based on net expression of the F gene  $(\widehat{z}_F)$  relative to the feminization and masculinization thresholds  $\theta_{\rm F}$  and  $\theta_{\rm M}$
- $M_{\gamma}$  and  $M_{\Delta}$  function as masculinizing genes by breaking down the feminizing F product
- Mutations can occur in F expression and sensitivity as well as  $M_{\nu}$  and  $M_{\Delta}$  expression
- Small proportion of mutations are null mutations that set trait value to 0
- $M_{\Lambda}$  becomes expressed de novo at a rate  $\mu_{\Lambda}$

*M*-dependent breakdown

# Total F product $\widehat{Z_F} = \sum_{i=1}^{2} \max(0, (Z_{F_i}(1+\beta T) + \varepsilon)(1-S_{F_{M_i}}) + Z_{M_{A_i}}))$ Temperature effect (Gaussian) coefficient F expression (with temperature effects and noise) Total M expression Total M expression Total M expression

#### Conclusion



Environment modulates scope for evolutionary change, promoting divergent evolution leading to polygenic sex determination

#### Funding

### Research





# Read the paper!

