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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?



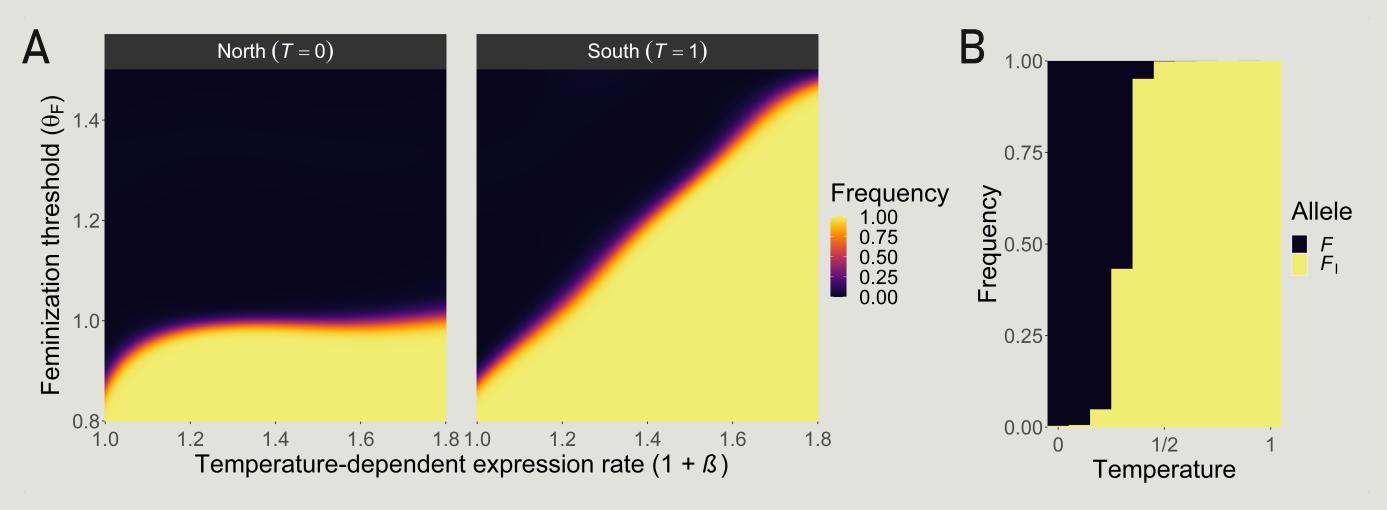
← Environment **→**

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

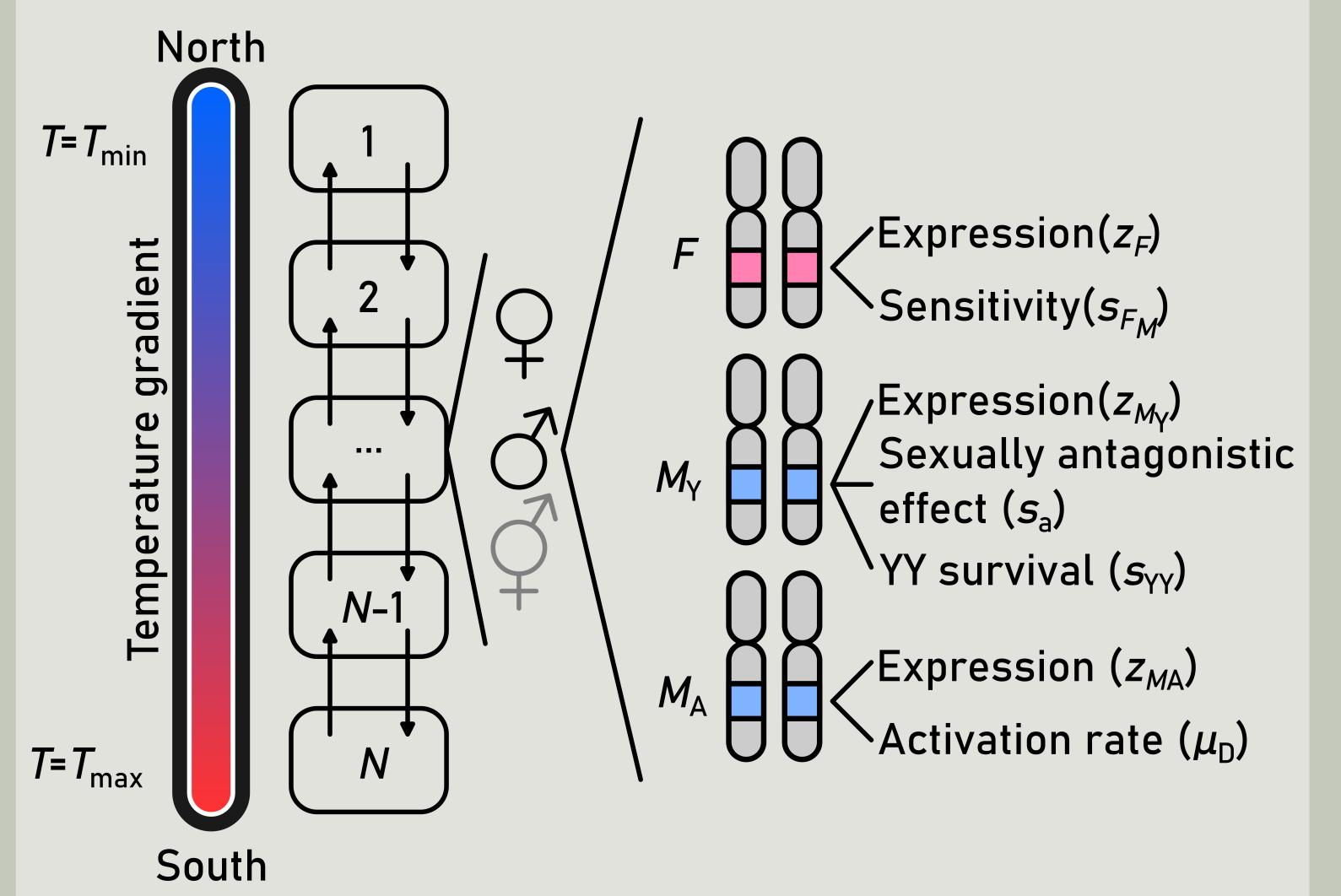
Evolution of a dominant feminizer F_1

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



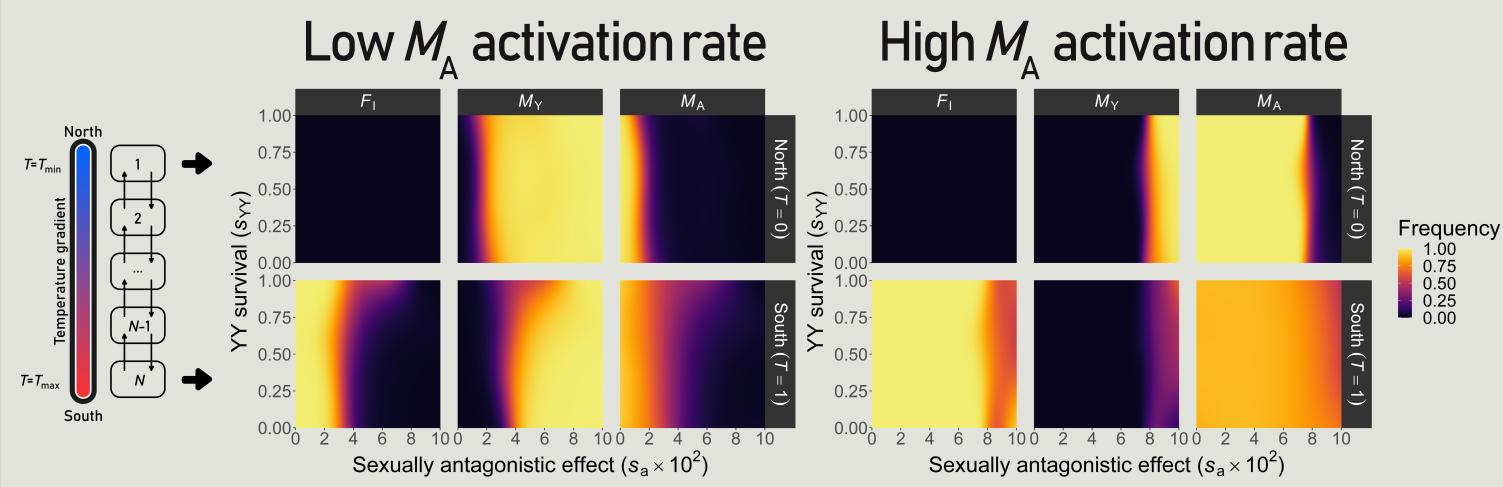
- (A) F_{\parallel} evolves when feminization threshold $\theta_{\rm F}$ is low (left) or when temperature-dependent overexpression becomes sufficiently strong (right)
- (B) Temperature-dependent invasion of F_{\parallel} may be restricted to warmer demes; environmental variation leads to within-population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

Model overview



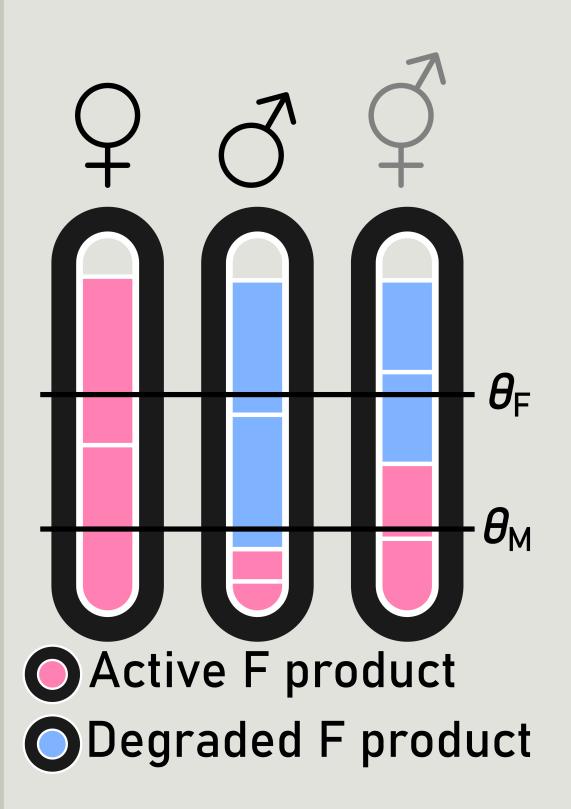
- Agent-based simulations
- Demic population with dispersal
- Non-overlapping generations
- Ancestral Y-chromosome M_{γ} with fitness effects
- *De novo* evolution of M_A

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_{γ} versus M_{Δ} polymorphism: sexual antagonistic selection maintains M_{γ} over M_{Δ} in absence of F_{γ} ; costs in females and reduced viability in YY homozygotes drive M_{γ} loss, followed by fixation of M_{Δ} in presence of F_{γ}

Sex determination gene functions and evolution

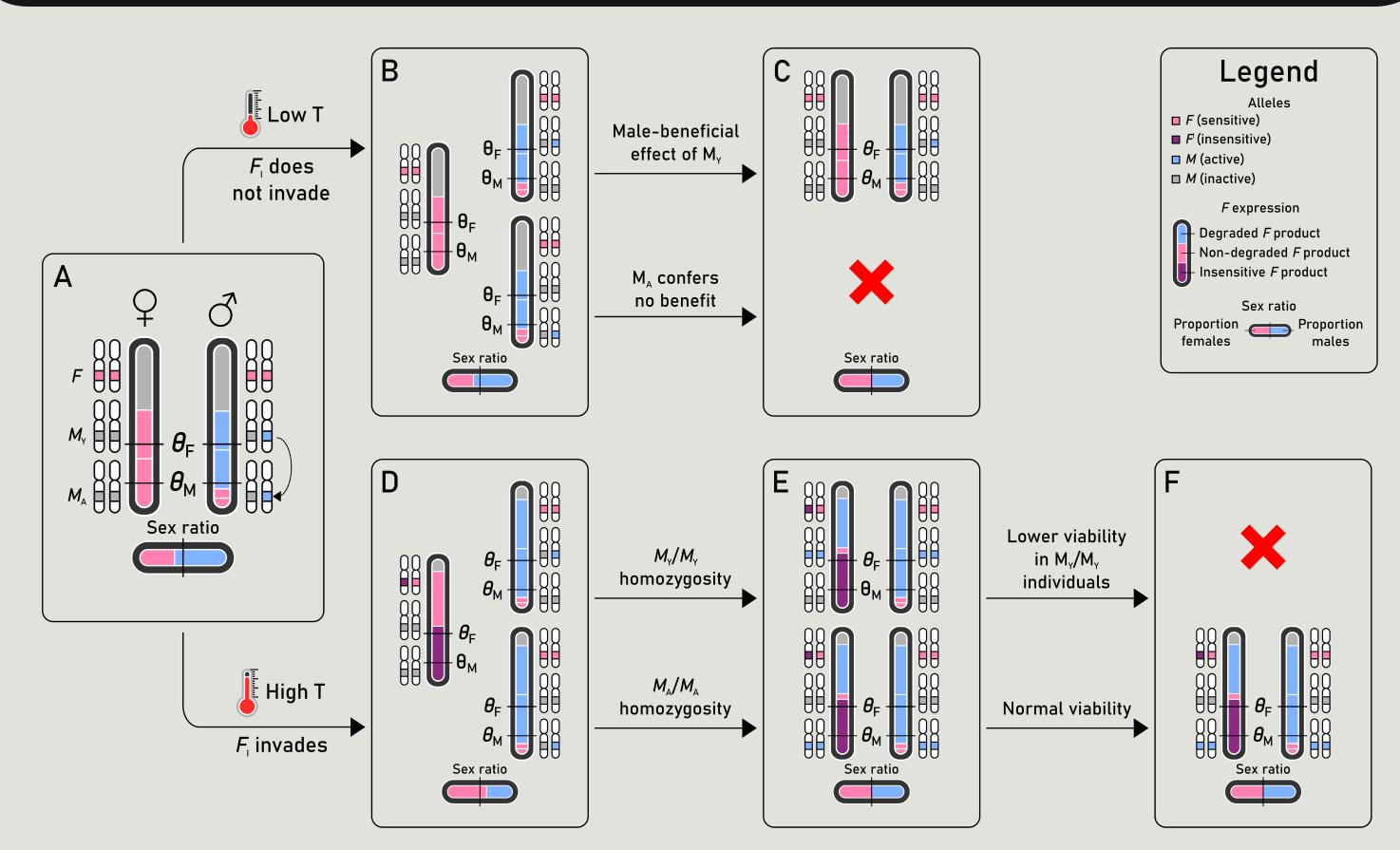


- Sex is determined based on net expression of the F gene (\widehat{z}_F) relative to the feminization and masculinization thresholds $\theta_{\rm F}$ and $\theta_{\rm M}$
- M_{γ} and M_{Δ} function as masculinizing genes by breaking down the feminizing F product
- Mutations can occur in F expression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

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!

